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# OPINIONS OF THE PRESS

ON THE

# FAIRLIE ENGINE.

BEING

## A SERIES OF ARTICLES

REPRINTED FROM THE

LEADING SCIENTIFIC AND OTHER JOURNALS.

LONDON:
PRINTED BY C. WHITING, BEAUFORT HOUSE, STRAND.
1868.

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Opinions of the press on the
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# INTRODUCTION.

In placing before the public the following collection of articles, reprinted from the leading scientific and other journals, a few words of explanation may be deemed necessary. When, a few years ago, the "Fairlie" engine was first brought under the notice of railway men, the arguments advanced in its favour were met with a certain amount of disbelief. Since that time, however, the teachings of experience have proved the principles upon which the Fairlie system is founded to be perfectly correct ones, and not only have the objections raised to it been, one by one, overruled, but, what is even more important, engines have been built upon Mr. Fairlie's plan, and have been found to answer fully all the expectations of their designer. It is in support of the facts here stated that the following articles and letters have been reprinted. And here it may be remarked, that the articles now given form but a very small proportion of those treating on the subject, which have appeared in the various scientific and popular journals. To have given the whole of such articles *in extenso* it would have been necessary to extend the present pamphlet to a bulky volume; and a selection has therefore been made of such articles as represented fairly the opinions of the various journals in which they appeared. In addition to those here given, many other articles, expressing highly favourable opinions of the Fairlie engine, have appeared in *Engineering*, *The Practical Mechanics' Journal*, *The Engineer*, *The Mechanics' Magazine*, *The Times*, *The Standard*, *The Globe*, *The Morning Herald*, *The Morning Post*, *The Morning Star*, *The Railway News*, *The Railway Record*, *The Illustrated News*, *The Illustrated Times*, *The Money Market Review*, *Herepath's Journal*, *The Liverpool Mercury*, *The Brazil and River Plate Mail*, *American Railway Times*, *The English News*, *The Home News*, &c. &c.

# OPINIONS OF THE PRESS

ON

# FAIRLIE'S SYSTEM OF LOCOMOTIVE ENGINES.

## THE FAIRLIE ENGINE.

*Extracted from a work on Railways and Locomotive Engines by Lewis Gordon, Civil Engineer, late Regius Professor of Civil Engineering and Mechanics in the University of Glasgow.*

A careful study of the drawings of Fairlie's engines, published from time to time in *Engineering*, has led me to this conviction, and induced me to inquire into the history of the Progress, an engine of 40 tons weight, constructed by Messrs. Cross in 1865 on Mr. Fairlie's designs.

The following is the report I received from Mr. Charles Liddell, Civil Engineer, who, in company with numerous other engineers of note, went purposely to Neath, in Wales, to test one of Mr. Fairlie's engines. The trial took place on the 7th March, 1868:—

*Report of a Trial of Fairlie's Engine, the Progress, on the Neath and Brecon Railway on Nov.* 9, 1868.

Pressure of steam in boiler, 8½ atmos., 130 lb.
Diameter of cylinders, 15 inches.
Number of cylinders, 4
Length of stroke, 22 inches.
Diameter of wheels, 54 „
Number of wheels, 8 on two "bogies."

| | | | |
|---|---|---|---|
| Heating surface. | Firebox, | 112·6 | square feet. |
| | Tubes, | 1980·0 | „ |
| | Total, . | 2092·6 | „ |
| Area of firegrate, | | 20·6 | „ |

Weight of engine empty, 38 tons.
Water and fuel, 6 „
Weight at starting, 44 „

| | | |
|---|---|---|
| Weight for adherence. | Max., 44 | tons. |
| | Mean, 42 | „ |
| | Least, 40 | „ |

Wheel base, 5 feet.
Average speed, 14·3 miles per hour.
Ruling gradient, $\frac{1}{50}$.

Curves, 8 to 40 chains on the main line, 4 to 10 on the sidings and branches.

Load—5 *empty trucks*, 15 *full*, 1 *break van;* 202 tons gross in 21 wagons or on 84 wheels. Total weight in motion, 246 tons.

The line rises continuously from Neath Junction to Onlwyn with gradients varying from 1 in 50 (0·02) to 1 in 66 (0·01515), with short lengths here and there of flatter gradient. Towards Brecon there are several long lengths of 1 in 57 (0·0175), and even 1 in 50 (0·02), where the embankments had sunk. *The ruling gradient* may be stated as 1 in 50.

The day was drizzly, with damp rails. The adherence was good at 1 in 66, but only maintained by sanding on 1 in 57 and 1 in 50.

Steam at starting, 130 lb. pressure.
„ at arrival, 125 lb. „

There was always abundance of steam, and but for the slipping the speed might have been increased.

Almost the whole length of the line is on curves of from 8 to 40 chains radius.

The distance run was 10¼ miles in 43 minutes = 14·3 miles per hour.

The consumption of coal and water was about 3½ tons by calculation; the weight for adhesion was about 40 tons.

The Progress has been in work for nearly two years; has never undergone proper repairs; has been disgracefully misused; many bolts and nuts in the plates and stays and cylinder fastenings being wanting. Also one of the axle-boxes was broken, and the spring blocked up with a piece of iron, shoved in *ad hoc*.

The return trip was run in 50 minutes. We stopped on the incline of 1 in 57, and shunted back; we also stopped at an intermediate station to put in some empty trucks and bring out full wagons. The time on the return trip, exclusive of stoppages, was 30 minutes, or the speed in descending was about 20 miles per hour.

The rails being slippery and the train special, the speed had to be kept down.

The wheel flanges, after two years' running, show little or no signs of abrasion from side friction, although the whole line is, as already stated, on curves of from 8 to 40 chains radius.

We made the engine run backwards and forwards through a siding, and the points and crossings connecting it with the main line at each end, the curve of the siding being about 6 or 7 chains radius; the road as to gauge, level, and general condition being in bad order.

The Progress went through it easily and noiselessly, and, to us riding on it, the smoothness of motion was quite remarkable; much smoother than an ordinary Great Western first-class carriage. The engine travelled with perfect steadiness, without oscillation; so the train followed without oscillation, forcibly indicating that oscillation at such speeds is due to the ill-balanced ordinary engines.

The objection to Fairlie's engine, usually made with perfect confidence, is that the motion of the steam pipe joint is so great that *it cannot be kept tight*. Now, although there was some trouble on this head at first, the steam pipe of the Mountaineer has been at work for 2½ years, and is said to have stood well. In the Progress the joint is put in the wrong part of the engine, close to the cylinders, at the furthest point from the centre of the engine, so that the motion is actually the greatest possible, the play being 2½ in. on either side. *And yet the joint seemed fairly tight.* If the joint were at the centre, the motion would be greatly reduced, and there cannot be any real difficulty in making a tight joint.

From the facts recorded in the report, I calculate the *power* the Progress exerted to have been 560 H.P. as follows :—

| | |
|---|---|
| Resistance of locomotive as vehicle . . . . | 0·00522 |
| Additional resistance at periphery in curves and on centre joint . . . . . . . . | 0·00150 |
| Total . . . . | 0·00672 |

which we may take as 15 lb. per ton.

| | | |
|---|---|---|
| 40 tons at 15 lb. | | =600 lb. |
| 202 tons in train on bad road, and load ill-adjusted | 0·004 | |
| Extra resistance in curves | 0·006 | |
| Total | 0·01 | |

or 22·4 lb. per ton.

| | |
|---|---|
| 202 × 22·4 | 4524 |
| Total | 5124 |

or 2·3 tons.

Resistance from gravity $=\frac{242}{57}=4{\cdot}24$ tons.

$4{\cdot}24+2{\cdot}3=6{\cdot}54$ tons as total resistance, or maximum tractive effort.

$6{\cdot}54\times 6\times 14{\cdot}3=560$ H.P.

The adherence $\frac{6{\cdot}54}{40}=\frac{1}{6{\cdot}11}$ under the influence of sanding.

The resistance on 1 in 66=5·96. And as the weight for adherence was 42 tons, the co-efficient of cohesion was $\frac{1}{7}$ in "*wet, drizzly weather.*"

In dry weather the Progress is said to be able to take a load of 300 tons gross over the Neath and Brecon Railway.

## DOUBLE BOGIE LOCOMOTIVES.

*From Engineering, August* 28, 1868.

It is promised that, in July next, the last link in the through line of railway from New York to the tidal waters of the Pacific Ocean will be completed. The whole distance is about 3300 miles, and although there are ferries and breaks of gauge, the line may be regarded, when once opened, as practically unbroken. The general direction of the line is nearly due east and west, practically following the 40th degree of latitude. At the western extremity the line ascends from Sacramento, at the sea level, to the summit tunnel in the Sierra Nevada, or Nevada Mountains, the ascent, in a distance of 105 miles, being no less than 7042 ft., and the average inclination, therefore, 1 in 67 for the whole distance, while for 6 miles there are gradients of

1 in 45½, or 116 ft. per mile. This portion of the line has been working for some months, and trains are, indeed, running considerably to the eastward of the Nevadas. It may be recollected that we gave a comparative full description, together with numerous illustrations of this line, in *Engineering* of August 2, 1867, vol. iv. p. 80. The consulting engineer to the Central Pacific Railway Company of California, Mr. George E. Gray, has decided upon a trial of Mr. Fairlie's double bogie engines, so strongly recommended, by the way, by Captain Tyler, for the Grand Trunk Railway of Canada, and an American locomotive maker, Mr. William Mason, of Taunton, Massachusetts, is constructing it from the leading designs of Mr. Fairlie himself. Any of our own locomotive engineers who have visited the States must be more or less familiar with the engines of Mr. Mason, who, long a maker of other descriptions of machinery, commenced this branch of construction in 1852. It is but just to say that in neatness of design and in carefully considered detail, they rank among the best of the American type—to which, by the way, our own practice appears to be tending in some few respects, if one may judge from the Metropolitan Railway engines, and the new engines by Mr. Adams, of the North London line, as well as some on the Stockton and Darlington line, and a good many made by Messrs. Neilson and Co. Messrs. Fox, Walker, and Co., and possibly others. It is to be hoped, therefore, and with good reason, that the double bogie engine, originally made, in a somewhat different form, many years ago, at Seraing, in Belgium, and, within the last three or four years, in England, will at last have, what it never yet had, the advantage of a high order of design, and of that careful forethought which would have anticipated the loss of the nail which lost the shoe, and thus the horse, the rider, and the army.

The double bogie engine has been discussed and rediscussed, both in our own columns and elsewhere, but seldom, if ever, upon the ground of its real merits; and although it has the demerit of complication, it certainly does possess merits, possibly of enough magnitude to more than overweigh the objections under this head. But the purely locomotive engineer is not so apt to see these merits as is the civil engineer, and especially the permanent way engineer. The former looks upon the permanent way as a camel's back, fitted to bear any and all burdens—burdens which no final straw can break. But just as the strength of a chain is the strength of its weakest part, so is the greatest load per wheel of a train the measure of the necessary strength of the permanent way. It must be twice as strong to bear six tons on a wheel as would be necessary for three tons—earthwork, ballasting, sleepers, chairs, and rails—everything must be twice as strong. And so it must be if but two or four wheels of all that are in a train press with a force of six tons each, and the hundred or two hundred others are loaded only to half that weight. The line must be made for the maximum, not for the average nor the minimum, load per wheel; just as the Board of Trade officers will pass a bridge only when it has been tested with the greatest load that, in their opinion, can possibly come upon it, even although the ordinary load be but half as much.

There will be plenty to deny, and that under the influence of sheer habit, that the permanent way could be made no lighter than now, even were the heaviest engine weights but 3 tons per wheel. Common sense, however, teaches better than this, and even a lawyer, doctor, clergyman, or plain farmer might safely contradict the most "eminent" engineer who would presume to tell him so—if, indeed, a really eminent engineer had such presumption. The wear or abrasion of the head of the rail is not, it is true, dependent merely (although it is to some extent) upon the maximum load per wheel, and probably two wheels loaded to 3 tons each will cause nearly as much superficial *wear* as one loaded to 6 tons, although they will knock the way to pieces to a far less extent.

Others will say, that inasmuch as our lines are laid for weights of from six to eight tons per engine wheel, it is too late now to consider the question of lighter permanent way. So it is, yet our existing permanent way would, indisputably, be maintained in better condition, with less platelayers' labour, were our maximum weights but three or four tons per wheel. We fully agree with many who would not listen to any reduction in the strength of the way, unless in the face of the strongest pecuniary reasons; but it requires no argument to prove that with the present standard of strength the line could be more easily and cheaply maintained in first-rate condition were the greatest weights no more than three or four tons per wheel. Even our present strongly laid lines—and steel rails have long since become a necessity rather than a mere advantage on many railways, such as those in and near the metropolis—are horribly overworked with our present engines, some of them having 8 tons on a wheel.

Another fault of the existing types of engines is that the weight per wheel but seldom approaches anything like equality on all the wheels. Of six-coupled engines, the leading wheels may be loaded to 7 tons each, while the trailing wheels may bear only five, although six on each of both would be preferable.

The only way to diminish the weight per wheel of a heavy engine is, necessarily, to increase the number of wheels, and the engineers of the Northern Railway of France are employing 59-ton tank engines with twelve wheels, loaded to 5 tons on a wheel. These are pulling coal trains such as are never seen on English lines—forty-five fully loaded wagons up 1 in 200, and, the managers of the line assert, with marked economy. But the twelve wheels are not driven by one pair of pistons. There are four cylinders, two to each group of six-coupled wheels. But these distinct groups are not bogies, all the axles being parallel, although the first and last axles of each group have considerable end play. The wheel base, therefore, is nearly 23 ft. long, and the engines thus strain the way laterally, and are often breaking their axle boxes. In any case such engines, having, too, all, or nearly all, the complication of the double bogie engine, must work with considerable friction. And we believe that their evident defects, and, possibly, the awful fact that they are "un-English" (!) have sensibly prejudiced engineers here against the double bogie engine, which, although having many points of external resemblance, is a totally different machine.

The great points in favour of the double bogie engine are these: it admits of at least twice (and that an equal) subdivision of weight per wheel attainable with an ordinary engine. If such an extreme subdivision of weight be not desired, then it permits of the construction of a heavier and more powerful engine, with a given weight per wheel. So long as it has less than twice the number of wheels of an ordinary engine, it admits of shorter individual wheel bases, and, indeed, this will generally hold good even where twelve or sixteen wheels are employed, the length of wheel base of each bogie not exceeding 8 ft. 6 in. where six 4 ft. wheels are employed in each. The engine, as a whole, is at the same time very steady. Indeed, Captain Tyler, of the Board of Trade, after carefully making himself acquainted with the large double bogie engine on the Neath and Brecon Railway, could only compare its motion over new and sharply curved portions of the line, to "sailing;" which might almost be said of double bogie passenger carriages, as any one will omit who has once rode in them. The double bogie engine is equally adapted for outside or inside cylinders. And it is an advantage of perhaps some little importance that so long as the right quantity of water is in the boiler, the firebox is always properly covered, whether the engine is going up or down a gradient of any practical steepness.

There are those to whom a double bogie engine, with its boiler of double length and its two chimneys, appears as two engines, and they naturally ask why not have two separate engines at once, so that if one were in the shop for repairs, the other might still be at work? Two engines, however, require two drivers and two firemen, and a good deal of care to start and work in concert. But, then, there is the plan of working two engines footplate to footplate, with but one driver, and possibly but one fireman. The objections to this plan have been pointed out before in our pages, and we know of but one line, the Turin and Genoa, where it has ever been resorted to. The driver's attention, sufficiently occupied with one engine, is divided between two of every lever, handle, rod, or whatever else he ordinarily has to touch—two regulators, reversing levers, brakes, steam gauges, glass gauges, dampers, and steam blowers in chimney, two sets of pumps, safety valves, cylinder cocks, blow-off cocks, and sand boxes—at least twenty-four distinct claims upon his attention, where, with a double bogie engine, as with an ordinary engine, he would have but twelve.

In proportion as our railways have grown into vast systems, several of them now working, each, more than 1200 miles of line, so has the difficulty increased in respect of any radical changes in the rolling stock. There is an objection to anything like experimenting so long as it can be avoided, and, of course, if we are to go on for ever, in the old jog-trot fashion, along the hard beaten, if not macadamised, path of routine, we shall never need to experiment at all. It may be, too, not unnaturally perhaps, that a certain class of engineers, holding appointments, do not care to take up the ideas of outsiders. It might seem to afford room for reflections upon their own qualifications were they to do so. They are supposed to know their business. Why, then, be taught by others? But the necessities of traffic, rather than the likes or dislikes of locomotive superintendents, must yet compel the adoption of something like the double bogie locomotive.

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## MR. FAIRLIE'S SYSTEMS OF LOCOMOTIVE ENGINES.

*From the Practical Mechanic's Journal, April* 1, 1868.

Dogmatisms and their authors, as well as dogs, have their day, and their day only; though their lives are always long in proportion to their authority, which is the co-efficient of dogmatic power with the chief part of mankind.

In very early railway days the Stephensons announced as one of the articles of belief, based in the *cosmos* and not to be gainsaid, that no railway with a ruling gradient steeper than 1 in 250 could be worked with economy, therefore with advantage; and Dr. Lardner followed by an equally dogmatic oracle, that no railway with a curve upon it of less than a mile radius could be worked with safety. These articles of belief, however, like the credence in witchcraft, whatever grain of truth they had in them, have died out, and engineers now act upon principles not a bit less exact as regards the recognition of natural laws, but with a far broader appreciation of conditions.

Without denying the fact that a very slight increase of gradient may double the tractile power necessary, nor Lardner's truths as to the relations between curve-radius, centrifugal force, and flange friction, &c., they now see that far wider and more complicated conditions—financial, social, political, military, fiscal, in relation to capital possible or advisable, and a thousand others—enter the question of what gradients and what curves it may be advisable to adopt in order to secure the formation of a line of railway between given points. They know full well that, whatever may have been done upon the comparatively level bed of consolidated mud and dirt of which our own larger British island mainly consists to the southward, the configuration of the crust of our globe itself forbids the possibility of uniting distant continental provinces or kingdoms, separated by great natural barriers from each other, unless by the adoption of steep gradients and curves often of extreme sharpness. Theoretic exactitude remains just where it was, but it has to submit to be shelved in presence of the actualities, which, if they are to be met at all, can only be met by compromises.

Very much the same review might be had of the history of locomotive-engine improvement and extension since the days of the memorable Rainhill competition, when the locomotive really first sprung into existence, by revealing at once all its before unexpected power and speed—unexpected, beyond doubt, even by its then constructors, or, as the Stephensons are even still popularly deemed, its creators—like Minerva springing in full panoply from the brain of Jove. And yet the differences in the subsequent careers of the railway and of the locomotive, have been quite as curious and instructive to trace. At first lightness was deemed indispensable in the locomotive, the condition without which it was assumed that speed was impossible. But the Rainhill trials dissipated that bit of theoretic mist at once, and showed that power, *i.e.*, rapid generation of steam at high pressure, was the condition of speed.

The effect of lightness soon began to show itself in want of adhesion in proportion to the load to be drawn; and then at once began that career which is even yet not ended, in which the ever-expanding wants of traffic have urged on a continually increasing weight of engine, necessitated at once by the need for greater evaporative power, higher pressure, and the machinery to employ these, and by the equally imperative demand for adhesion, or grip of the rails, to drag the heavier and still heavier loads. From this has followed continual increments of weight, strength, and cost of permanent way to bear all this; and at last a limit begins to be seen, at least to the possibility within contemplable cost, of extending the resistance and endurance of permanent way, even when steel rails shall have (as no doubt they will) become very largely, if not universally, the substitutes for iron ones: yet the limit of the demand for haulage, and the accessions of weight and power in the locomotive, still goes on.

Dogma has but little affected the history of the locomotive: theory, worthy of the name, had little to do with it until after it had sprung into existence an almost completed machine. Thenceforward its history nearly to the present hour, though illumined by many able contributions from science or theory, has really been little more than groping trial and error. One man has added this, another improved or modified or adapted that: better tools, more capital to work them, general metallurgic advances, special shops for locomotive building, the concentration of many minds of a high order upon a vast and lucrative industry, and the pressure of competition (both in the engine maker's and the engine employer's cases), have all converged to make the locomotive of to-day the splendid instrument of power and monument of human skill and perseverance that it presents to us, in its finest types, at the present hour.

But with all this it is marvellous to observe how the great outlines, "the archetype skeleton," as it were, of the oldest designs, remain as those in which all these multitudinous improvements in detail inhere. In general form, in fact, the very best types of engines upon nearly all our great British lines do not very materially differ from those of engines built a quarter of a century ago; and however improved they may be as to detail, it is because in maintaining these types we shut our eyes to the glaring evils and difficulties which they inevitably bring adherent with them, that locomotive power remains the wasteful and tremendously costly element of railway traffic which it is well known to be, to those initiated into railway management and accounts. The early locomotive had "a tender" to carry its water and fuel, and except in tank engines, which are themselves exceptional, we have a tender still. It was a light affair at first, for the evaporative power and distances run did not demand a great load of water or of fuel; but it has been always growing, and the weight of the tender itself has grown out of all proportion to the load put upon it. The greatest proportion by far of the gross weight of the tender consists in the wheels and axles, springs, brakes, framing, and plate surfaces. It not uncommonly weighs 12 to 15 tons, while its useful load is often as small as 2 or 3 tons; yet all this must be dragged along; its ponderous wheels and axles are of no real use but to give the structure something like proportional inertia, to prevent its being, in fact, as a mere tin kettle at a dog's tail between the heavy engine and the heavy train, and to enable them to perform the functions of a brake carriage to both of these.

It seems an incredible thing to find a passenger engine, for example, on the broad gauge, with the six-wheeled tender, together running on *seven* pair of wheels, and yet out of all these seven only one pair effective for traction: this one pair of driving wheels made to crush into the rails by an insistent pressure sometimes of 15 or 16 tons upon them, in order to get bite enough to be able to drag all the other useless dummies or rollers after them: to find that of the gross weight of the engine and tender in running order (11 tons being water and fuel), viz. 61 tons, no less than 47 tons is dead load, useless so far as having anything to do with the traction of the load behind is concerned, except to produce steam, and to expend it in power upon the one pair of driving wheels: to find that the loaded tender weighs nearly 24 tons, and does nothing in the way of service, but carry the fuel and water to make the steam, and interpose its own mass as a buffer, it may be, between engine and train, and act as a brake when stopping is needed. Brunel at a very early period saw some of the inconsistencies of this, and made some costly but abortive attempts to remove them. Hawthorn, of Newcastle, more than twenty-five years ago, built from his designs a compound sort of engine, in which the boiler was placed on one frame and carriage, and the engine, with ten feet driving wheels, and water upon another, the boiler carriage having the brakes; but still, of the four pairs of wheels and axles, but one was of any use for traction. The tank engine attempted to get rid of some, at least, of the unproductive load of the tender; but here new difficulties, through adherence to ancient types, were soon met. R. Stephenson had lengthened out the barrel and tubes of the boiler; he and others had wisely lengthened out the firebox, or even put one behind another; and he had adopted what the United States had originated, the substitution of the bogie for the two rolling pairs of wheels and axles of the engine. But the "bogie," on the whole, met little favour in England; it was ill designed, and worked stiffly and even unsafely, and in the main all British locomotives held fast by the time-honoured models, and had rigid framing and rigidly parallel wheels and axles. The wheels were long limited to four, then came six, and at last two of these coupled at each side. A short wheel base was deemed, and justly while things were so, indispensable to safety in going round curves. Mr. Bury, while he ruled upon the northern end of the now London and North-Western, insisted that more than four wheels to any engine was dangerous on this ground, and, in fact, gave up his post rather than his opinions. This was long before Adams had devised his swivelling axle bearings, even yet an exceptional appliance, if even a perfect one; and "coning" alone did whatever was done, to enable a six-wheeled engine to grind round a curve of anything like short radius. Hence the length of wheel base was as rigidly limited as the parallel axles and frame were themselves rigid, and so even with six wheels the Stephenson long boilers were found at high speeds, and with a road uneven or out of order, to plunge and "gallop" in a fearful way; and here was and is one of the limits of the tank engine—whether the water load be distributed below the boiler or saddled up above it, or both, the centre of gravity of the whole structure is probably always, but certainly in the latter case, raised, and the fuel upon the foot plate adds its weight far towards one end. The overhang of load beyond the length of wheel base becomes greater still, and the "galloping" plunge of the tank engine at speed becomes far worse than in the long-boiler engine alone, not only because of the distribution of the load over the same short base, but because the inertia of the load itself is increased. But another class of reasons set a limit to the use of the tank engine: upon the three or even four pair of wheels it is not possible to find room for enough water and fuel to carry a heavy engine through a long stage without stopping, such as from Rugby to London, or London to Brighton. The tank engine is thus the merely exceptional instrument of small or short traffic, and the useless dead load of the tender, as well as its tremendously heavy structure, remains the rule throughout Great Britain.

But were the tank engine universal (and it is far more common on the Continent than with us, and arranged to run longer stages), still it can do nothing for the "adhesion difficulty." With our best-laid permanent way, a rolling load of more than 5 tons upon any one wheel, means the rapid destruction of the way, and proportionate cost for restoration. With a rolling pressure approaching double this upon any one pair of wheels (6 to 8 tons not being uncommon on driving wheels), and especially with steel tyres, the rails themselves are crushed into, rolled out upon the top table, laminated into shreds, and destroyed. Yet this is what *must* be done when the entire "bite" for the traction of a heavy train must be provided for and got out of a single pair of driving wheels. The insistent *static* load is no doubt less upon each wheel where two pair of drivers are coupled; but were we to spare space enough to go lengthily into this subject, which from its ramified and conditional nature we feel cannot be done full justice to otherwise, it might easily be shown that with such coupled wheels, and the existing types of engines, the static pressure upon each pair of wheels is very far from representing the actual destructive energy of the same upon the way. In fact, two pair of drivers may be coupled; the static load upon each wheel, as proved by the weigh bridge, may not exceed 5 tons, and yet the hammering power, *quoad* the rails, of the pair farthest away from the centre of gravity of the engine, may be as great as that of a single pair loaded with 6 or 7 tons each, situated close to the centre of gravity; and in this case we will assume an engine well balanced as to its working parts; if these be out of balance the plunging of the leading or trailing pair of drivers will be further exalted.

The limit having been reached at which no more pressure upon driving wheels is possible upon a given line of way, unfavourable gradients, time, or heavy traffic still urging for better haulage and better bite, the expedient is resorted to of working with two engines. We do not here go into any consideration of what this means or infers in point of drivers' and stokers' wages, repairs, interest on capital in rolling stock, and so forth. One engine very generally runs backwards; in other words, its trailing wheels become leading wheels. As one element of allegeable use in the ponderous dead weight of the tender is, beyond question, that being coupled hard on to the engine and dragged behind, its mass tends to steady the plunging of the engine due to its narrow wheel base; so here, the two tenders, no doubt, do tend to steady both coupled engines, and reduce the amount of risk that is always run by running engines backwards. But no engine whose heaviest insistent pressure is upon a central pair of driving wheels, with much smaller diameters of leading and trailing rolling wheels, ever *can* be a safe rolling system.

It is demonstrable upon simple principles, that the maximum of safety as against leaving the rails upon either a straight or a curved line will, *cæteris paribus*, exist where the leading wheels, being also those of largest diameter and the most advanced in the engine, are the driving wheels, and when all others are following or trailing wheels. This, although exceptional constructions can be pointed to, may be said to be impossible with our common types of locomotive. The directive power of coupled driving wheels when thus posited is, upon a perfectly straight line, amazing. The writer was last summer upon the Northern of France Railway when a six-wheel (four-coupled leading drivers) locomotive, hauling an express train, was thrown partly off the rails, by either a bad joint or a hollow sleeper. The two leading driving wheels were thrown off only, and in that state the engine and train ran along for more than half a mile before being stopped; the wheels that were off, keeping all the way so close to the rails as to shear off the fish-plate bolts nearly all along the track, and yet never diverging further. Without six wheels, this could not have occurred, but with six wheels, had the middle ones alone been drivers, the engine would probably have been over the side of the embankment of 35 feet high, where the accident occurred, within the first 200 yards.

Nearly all our engines are in fact, in type, *one-ended.* They are only designed to run with greatest safety—be that more or less—always with one end foremost. Hence the whole ponderous system, upon all our lines, of 45 or 50 feet turn-tables, and all their attendants, and consumption of time and labour, and capital, &c.; all the latter of which are doubled when two engines are employed as mutual assistants.

Now, all these disadvantages or evils hang together like "the house that Jack built." We can't dispense with a destructive pressure upon single pairs of driving wheels, because we must have adhesion; we can't distribute that adhesion amongst all the wheels under the engine, nor make the whole weight borne by all the wheels available for adhesion, and therefore useful for haulage in place of a mere rolling incumbrance, because we can't extend the rigid length of wheel base, and yet get round curves even of moderate radius, without danger of a smash; we can't diminish greatly the radius of our curves on new lines, nor employ very steep inclines, both of which are of the essence of economy in construction, because we can't get round sharp curves, and have not, with all the pinch on the two or four driving wheels that we dare give, enough adhesion to drag up heavy loads; we can't get rid of the useless incumbrance of the tender, because we can't carry enough fuel and water safely in any other way, or upon any ordinary type of engine; and we can't get rid of turn-tables, because we must turn our engines to enable them to run with the best amount of that moderate safety, of which only they are susceptible; and finally, we cannot materially increase power for a given total weight of engine, or even for a reasonable addition to it, because the diameter of the boiler is fixed by our unlucky 4 feet 8½ inch gauge, its height above the rails throws the centre of gravity already dangerously high, and the length cannot be extended, because that of the wheel-base cannot be so.

One can see without probably much uncertainty that in a remote future, after the 7 foot gauge shall have long been absorbed and lost in the narrow or 4 feet 8½ inches, that new and future legislation to meet future needs, will compel all the lines in the kingdom simultaneously to enlarge the latter gauge, and adopt either the Irish gauge of 5 feet 3 inches, or the Indian of 5 feet 6 inches; and whenever, if ever, that may take place, we can obtain more power through more boiler room; but that is a contingency not worth present speculation upon. What, then, is the clue that can bring us out of this labyrinth of difficulty? Mr. Robert F. Fairlie, C.E., has given the answer within the last four years or so, by the inventing and bringing into a practical working condition of his several designs of patent locomotives, and we do not shrink from uttering with clearness our opinion that he has given a full, distinct, and almost complete answer to the question. Parts of it had been answered before; the continental locomotive engineers—more original and exact in thought generally than our own, more alive to and more ready to change from old to new, and above all, less hampered with utterly unpaying lines on the one hand, and the ceaseless crush of an overwhelming and leisure and thought absorbing traffic on the other—have long been before us in surveying the difficulties at which we have here taken a rapid glance, and in devising more or less of remedy. As long ago as 1862, at our London Exhibition, Messrs. J. J. and A. Meyer, of Vienna, showed their articulated tank locomotive, in which (see our Record of the Exhibition, 1862), upon two distinct frames, each mounted upon six wheels all coupled, the engine is placed. Each frame had a pair of cylinders of its own, which drove all its three axles and six driving wheels, upon the whole twelve of which and of both systems, the insistent load was evenly divided, so that the whole weight of the engine was available for adhesion; and as both frames swivelled separately, like two large bogies, so a curve as short as could be gone round by the length of wheel base of either, could be safely traversed by this engine of 60 tons' weight, though pressing only with 5 tons upon any one wheel.

This engine was guaranteed to take itself and a load of 153 tons up an incline of 1 in 17, at 10 miles per hour. At the Paris Exhibition of last year were several engines, Austrian and French, with these two grand characteristics of uniform and light pressure, ample adhesion by coupled multitudinous wheels, sixteen or twenty in some cases, and swivelling frames or bogies to admit of going round short curves. It is nothing to us here at present how skilfully, or the contrary, some of these conditions were carried out in one or other of these various engines. But though these went so far, they stopped short of solving the whole problem; many of them were still dependent on tenders—though Messrs. Meyer's was a tank engine—and they all had one end which must for safety or by the other necessities of the case run foremost: even Messrs. Meyer's engine, though *quoad* the wheels and gear it could run with equal safety with either end foremost, must in one of the two; have the driver either like a "sculler" going where he could not see, or going with his back turned to his engine.

Mr. Fairlie, however, meets all the conditions of the problem, and thus first he says, Alter the type of your engine altogether; construct an engine that under all circumstances and conditions shall be able to run with either end foremost with equal safety and facility. That done, you have got rid of turn-tables for engines and tenders at a blow. Next, distribute the entire weight of your engine, and all its belongings, uniformly and symmetrically over such a number of pairs of wheel and axles as shall only give 5 tons maximum pressure per wheel; then apply power to all your wheels, and so make all your weight available for adhesion and traction. But for this you must have great length of wheel base, and great length of engine. Divide then your wheels and axles into pairs or triplets, according to the curves you have to encounter; place each set of these upon a distinct bogie frame, and give to each its distinct and separate pair of steam cylinders and pistons, &c. You now may safely make your boiler as long as you want; you may divide its total length as you please, nearly between firebox and tubes; you may therefore increase your power as you need it; and as you have now ample room, and are clear of all difficulty as to intense insistent pressure, which you have diffused, make your engine a tank engine, and the weight of its own water and fuel will be useful for adhesion, in place of a useless load to be dragged.

The type of engine which he has designed to fulfil these consists in something like two ordinary locomotives, with long-barrelled or Stephenson boilers joined into one at the fireboxes, which become in any one of various ways thrown into one firebox, taking out at opposite ends from two breasts two sets of tubes to two funnels at the extreme ends of the engine. The wheels and axles may be in number any multiple of two greater than four; but each pair or triplet has its own pair of cylinders, and swivels in going round curves upon its own bogie frame, all the system being handled from a single or from a duplicate system of regulators and hand gear. The footboards for the drivers, the fuel platforms, and the fire-doors are at the two opposite sides of the engine; so that the drivers, who can pass over the fireboxes or round the smokeboxes from one side to the other, are situated when running at the mid length and safest place on the engine. The water tanks can be kept low, and though the space for fuel is necessarily somewhat restricted, enough can be secured, and it does not seem impracticable to provide larger space even, if necessary, over the boiler or part of it. These engines are no longer a mere novelty. They have long been a subject of discussion and of controversy in the pages of the *Engineer*, and other technical journals. They have been running for a considerable time on some foreign railways, and upon the Brecon and Merthyr Railway in this country, and now probably on other lines.

The following official letter has been placed at our disposal, and indicates the opinion that Captain Tyler, R.E., of the Railway Department of the Board of Trade, has formed of those engines:

"Board of Trade, S.W., May 6, 1867.

"To W. L. Banks, Esq.,
"Chairman, Brecon and Merthyr Railway.

"MY DEAR SIR,—Referring to our conversation in the train on Saturday morning, and your subsequent note, I have much pleasure in stating to you the reasons why I should like to see Mr. Fairlie's engine more extensively employed. It does all that a tank engine or a steam tender engine can do as regards adhesion, inasmuch as all the weight of machine, fuel, and water, is upon driving wheels, and it has the important advantages that—

"1. It can run either end front with equal steadiness and safety.

"2. It is well adapted for very sharp curves.

"The disadvantages of tank engines increase in proportion to the speed, and inversely in proportion to the radii of the curves. They are trying to the permanent way, and in this respect far from economical. They are more trying, less steady, and less safe, as the wheel base is reduced to adapt them to very sharp curves. They are apt to leave the rails, and then to turn over, on meeting with inequalities of the permanent way.

"The motion of Mr. Fairlie's engines on the Neath and Brecon Railway appeared to be remarkably easy in rounding the curves, and I should be glad to have an opportunity of testing them more severely in these respects when I am next in South Wales. He will, no doubt, further improve in construction in future engines, and I should be glad to see such an engine made for the Brecon and Merthyr Railway, and fairly tested in all respects against the tank engines, from which Mr. Henshaw appears to have obtained such good results as regards economical working.

"Believe me to remain, dear Sir,
"Yours truly,
(Signed) "H. W. Tyler."

And in a more recent document, viz., his report to the directors of the Grand Trunk Railway of Canada, made in conjunction with Mr. C. W. Eboral, of the South-Eastern Railway, upon the condition and prospects of that line, dated December, 1867, and printed, Captain Tyler well explains the principal advantages of these engines, and distinctly recommends their adoption upon the Grand Trunk line, as the following passage taken from that report proves:

"The engines which find most favour in Canada, and generally in America, are constructed with a 4-wheeled bogie-truck under their leading, and four coupled wheels under their trailing ends. And engines of this description are now being built, to weigh about 32 Canadian tons, for future use on the Grand Trunk Railway. The tenders run upon two bogie-trucks. Six-wheel coupled engines, such as are used in this country, are apt to leave the rails on an uneven or frozen road, and it is not safe to use them in Canada. The disadvantage of the existing pattern of engine is, that neither the four wheels of the bogie-truck, nor the eight wheels of the tender, are available for adhesion; and that in order to obtain sufficient adhesion for heavy loads in slippery weather, a considerable weight is required upon the four driving wheels. It is a very important object, with reference to the durability of the rails—to which I shall hereafter refer, and especially ou a road-bed which is rigidly frozen for five months in the year, to keep the weights on the wheels as light as possible. The class of engine best suited to the climate, and for the various circumstances of the case, would, I have no doubt, be an engine running on two bogie-trucks—each provided with a pair of cylinders, and 4-wheeled or 6-wheeled according to the work required—and without a tender. Such an engine would be peculiarly safe to travel over a winter road; would combine a minimum wear and tear, to itself and the rails, with a maximum of adhesion, and would be the most effective and most economical that the company could employ. I had the opportunity some time ago of testing engines of this description on the Neath and Brecon Railway, designed by Mr. Fairlie, and have found the principle to be good, though certain points of detail required improvement. Such engines are also in use for the sharp curves and steep gradients of the Queensland Railway."

Amongst the subsidiary advantages secured by Mr. Fairlie's construction is the not unimportant one, that with a given normal depth of water over the crown of the firebox in his boilers, a much smaller disturbance of that depth (about one-half, in fact) is produced by the engines being upon an ascending or descending incline, than with the ordinary type of engine. This is of value when gradients of 1 in 40 to even 1 in 20 are getting not uncommon abroad.

There is probably no man, out of the direct bounds of experience in the profession of railway engineering, whose opinion on this subject is more worthy of deference and respect than is that of Captain Tyler, R.E., not only from his natural engineering talents, scientific training, and large opportunities of observation upon various railways—quite as good experience with an orderly mind and observant habits as any other—but from his well known probity and hatred of all falsehood and quackery.

At the same time, we are bound to notice that several of the best-known and esteemed locomotive superintendents in England have raised divers objections, and uttered hard opinions of the Fairlie locomotive, several of which may be found in the mechanical journals we have already referred to. We do not wish to be rude, or to excite hostility, yet we must not avoid venturing this remark, that so far as some observation and experience go, we have been obliged to regard locomotive superintendents, as a class, as a very prejudiced set of men upon all immediate professional questions, and each prone to condemn every system but his own. Nor is this very wonderful, nor causes for it far to seek, if we were to enter at length into the conditions under which these gentlemen have acquired their knowledge generally, and the formidable responsibilities, and cares, and labours, without leisure for exact study, under which they usually have had to exercise it.

Some of the objections which we have observed made to Mr. Fairlie's engines, by whomsoever made, do at least appear to us either untenable or of very small weight. But, on the other hand, we are not ourselves insensible to certain valid objections that may be urged against them as to matters of detail. It is scarcely worth while to take space to enlarge upon these. No machine was ever yet designed that longer experience did not point out defects in it which were soon found remediable, if alone the *principles* upon which all was based were sound. These we believe are sound and good here; and the *residuum* of objections that are based upon the employment of the principles Mr. Fairlie has adopted, or that seem necessarily to cling to these, appear to us to be few. Perhaps two of the most cogent of these would take this form:—No railway can be ensured to be a perfect plane upon the face of the rails, for even a few yards; it must be expected to have very often sudden hollows, twists, inequalities, within a few feet of each other; it will occasionally pass over culverts, level crossings, &c., where a short but positive *hump* may exist upon the line within a length less than that of one of those very long engines. The effect of these must be more or less seriously to strain and twist the entire system of such a long and flexible engine, and especially to derange the bearing surfaces of the engine, boiler, &c., upon the bogie frames, and with these all steam or other joints that have to pass from the boiler to the engine frames, through this shifting interspace. This is a matter only capable of being decided by the experience of rough and hard work, and then, if valid, to be met by improved arrangements in detail.

The other may be stated thus:—It may be admitted as a fact, that engines supported, as those of Mr. Fairlie are, upon bogie frames swivelling horizontally, round certain limits, and with all their wheels drivers, will be, while upon the rails, at least *as safe* upon a perfectly straight line of way (we believe safer), and upon any curve much safer, than engines of existing types. But yet it is conceivable that one or other of the bogie frames, most probably the leading one, and of that only the leading wheels, *might* by some means be thrown off the rails. In such an event it appears to us unquestionable that the tendency of the bogie, thus slewed over more or less as a whole, or with its leading wheels still urged forward in the new and abnormal path they had been forced into, must tend more rapidly and probably to make the whole engine diverge still further, and either to turn over or to run quite off the line, and in certain places with terrible results probably.

This is, however, one of a class of questions upon which no true light can ever be thrown by discussion of generalities. There is but one method either of urging *à l'outrance* or of refuting the objection. Take a given design for an engine, with weights and dimensions, &c., all known; assume a certain derangement, as, for example, the leading bogie thrown off the rails, and slewed to the maximum angle the frame and connexions will admit of with the line of motion of the engine; determine the dynamic effort in the centre of gravity of the whole imposed system at a given speed, and deduce the moment of stability of the system, and those tending to derange its former line of motion. These are really questions of *how much* always, and it is because argued upon mere vague generalities, that we think some of the objections urged with much "war of words" against these engines would, if thus tested, perhaps disappear totally in validity, while others would at least show their genuine value, if any.

It is uphill work, however, attempting anything in the way of improvement in railway rolling stock, in Great Britain at least. The circumstantial difficulties due to the pressure of traffic, of hard work on employés, and of finance upon Boards, &c., render even certain and assured advances slow and difficult; yet, in the end, what is genuine and right and sound, is sure to be *per force* adopted.

More recently Mr. Fairlie has applied his favourite principles in another form to a novel sort of locomotive for ascending steep gradients, such as that over Mont Cenis, wherein the weight of the passengers and their baggage are loaded upon the engine, so as to bring it in aid of adhesion. We must, however, reserve that to another article.—Ed.

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## THE PATENT LOCOMOTIVE ENGINES OF ROBERT F. FAIRLIE, Esq., C.E.

*From the Practical Mechanics' Journal, August* 1, 1868.

Until Mr. Fairlie took out his patents for improvements in locomotive engines, no other method occurred to our engineers for adapting the engine given to us at the very comencement of our railway experience by Stephenson, Blenkinsop, and Braithwaite, to the ever increasing demands of our traffic, than by gradually increasing their weight, which increase had either to be made in the length or height of the machine. The increase in the length, which means the wheel base, has long reached its maximum for safety; especially as engineers are now becoming daily more familiar with the necessity of making *railways to suit the circumstances* of the country to be traversed, instead of compelling, at any cost, circumstances and the country to *suit the railways*, as in the Stephenson time. This change naturally leads to more sharply curved lines, and lines with steeper gradients—in fact, to constructing cheap lines following the configuration of the country, instead of the expensively constructed straight and level lines of twenty years ago. The limit, however, to this method was reached when the ordinary type of engine became so heavy on the usual six wheels as to be found so destructive to the permanent way, that rails, even of steel, were found to last in some places but a few months. It was therefore necessary that something should be done to change the condition of the locomotive, to enable these lines to be worked economically; and Mr. Fairlie has grasped the whole question fundamentally and in the most practical form. The limit of load which it is possible for any one pair of wheels to carry economically being reached, it follows that, in order to obtain greater power than the locomotive at present in use can afford, we must employ engines with a greater number of coupled wheels. But it has been found in practice that coupling more than three pair of wheels together does not answer in the long run, so that we shall be compelled to arrange the wheels in two or more groups, each group driven by independent engine power.

The Fairlie engine, of which we herewith give a plate, is designed to meet the difficulties we have above alluded to. It has twelve wheels 4 feet in diameter, arranged, as shown, in two groups, each group being independent of the other, and being driven by a pair of cylinders 18 in. in diameter, with 24-in. stroke. Each bogie has a wheel base of 8 ft. 6 in., and this length is practically the rigid wheel base of the engine; the great length of the total wheel base, or the distance between the centres of the extreme axles of the two groups, in no way interfering with the engine readily traversing the sharpest curves. The total wheel base being 32 ft. 6 in., gives great steadiness to the engine, whilst, as will be seen, it does not interfere with its flexibility. The boiler is carried in a cradle or carrier frame, which is in turn supported on the two bogie frames. All strains, &c.,

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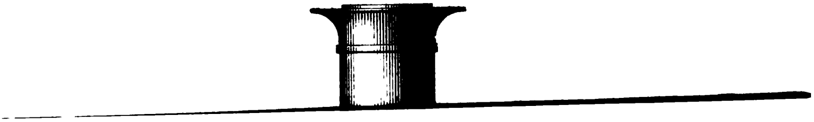

are taken up by the carrier frames; the boiler merely has to supply steam to the cylinders. The arrangement is, in fact, such that, could steam be supplied to the cylinders from any other source than the boiler, the engine would be perfect in every respect, if we leave the weight of the boiler, which is necessary for adhesion, out of the question. The tractive force of this engine with a cylinder pressure of 100 lbs. per sq. in.=33,400 lbs., which is equivalent to a gross load of about 390 tons up a gradient of 1 in 25, at a speed of ten miles per hour.

Several engines of this class are now in use. They are extremely easy, we are informed, on the road; and as the whole weight of the machine is equally distributed over a large number of wheels, the wear and tear both of the engine and the permanent way are consequently reduced to a minimum, while they adapt themselves with facility to the curvature and inequalities of the road without any of that grinding and jarring between wheel flanges and rails so common with locomotives of the ordinary type. The fuel and water being carried on the engine itself, the necessity for a tender is dispensed with, and the whole weight carried is made available for adhesion or grip on the rails. The bogies being free to swivel on their pins, each engine can radiate independently of the other; so whilst passing round even an S curve each bogie can accommodate itself to the direction of the curvature without in any way interfering with the action of the other. The boiler has two barrels, each 13 ft. long by 4 ft. in diameter, these barrels springing from a central firebox casing 10 ft. 6 in. long. The barrels contain 352 tubes, 2 in. in diameter inside, and the boiler has altogether a total heating surface of 2550 sq. ft.—an ample allowance. The grate surface is 32 sq. ft. It will be seen by referring to the Plate that both the regulator and the reversing gear are arranged to be worked from either side, so that the objection urged by some against this class of engine, that the engineman and fireman could not assist each other, if need be, is done away with.

The steam pipes, as shown, pass from the steam dome in the usual manner to the bogie frames near the cylinders, where they are connected by T-shaped pipes. The arms of these T-pipes are curved to arcs struck from the centre of the bogie pin; and they are free to slide in the ends of other pipes, also curved, which are attached to the cylinders or steam chests. The last-mentioned pipes are fitted, as shown, with stuffing boxes.

The steam pipes of the first engines constructed on this system gave considerable trouble; but this difficulty has been satisfactorily got over by the arrangement shown in the engraving.

By making the firebox in the centre of the engine, and having a boiler barrel running in either direction, great tube surface is obtained; and the firebox may also be made of any desired size, as the bogie frames may be placed any distance apart that may be required. The heaviest parts of the boiler are thus also placed nearest to the centre of gravity of the whole system.

That a complete revolution must take place in our present locomotive practice there can be no doubt. The locomotive of to-day is the same in all essential particulars as when it left the hand of Stephenson; we have only gone on increasing its size and weight. We cannot, with economy and safety, enlarge the present type of engine; it must be completely remodelled; and the engine which combines great steam-generating and cylinder power, and great adhesive weight with flexibility and safety, must be the engine of the future.

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## ALPINE RAILWAYS.

*From Engineering, May* 1, 1868.

Sir,—Within the last few years great and bold railway schemes having been projected and carried on with much vigour and enterprise on the Continent, and it is very satisfactory to find that the colossal mountain wall, clad in eternal snow, the Alps, forms no longer an insurmountable *barrière* to steam intercommunication.

In 1857, when Count Cavour's policy advocated a close connexion of Sardinia with France by means of a railroad *viâ* Mont Cenis, this great statesman's idea was met by a proposal to construct a tunnel, of not less than 12,220 metres in length, and at an elevation of 1338 metres above sea level, under the Col de Fréjus, between Bardonnêche and Modane, thus connecting Turin with Chambéry and Culoz, from which latter point the line branches off to Lyons and Geneva. Of the great tunnel through the Col de Fréjus—better known by the name of Mont Cenis tunnel—only about 4000 metres remain to be completed, which, it is calculated, will occupy about three years more. (The exact state of the workings were, at the beginning of April, 8049 metres against 4171 metres.)

Previous to this, however, as your readers will be aware, the Alps were pierced at the Semmering by a tunnel of 1431 metres long, and

897 metres above sea level. This route, which was opened for traffic on the 17th of July, 1854, connects Vienna with Trieste and Venice, and represents, properly speaking, the first Alpine railway.

Only a few months ago a third important connecting link was completed, situated 300 kilometres westwards from the Semmering, and connecting Italy with the traffic of South-Eastern Germany, viz., the Brenner line, which intersects the Alps at a height of 1336 metres above sea level, and by a series of short tunnels (the longest about 600 metres) between Innsbruck and Botzen, the natural configuration of the Alps at this point making no long tunnel absolutely necessary.

It happens, however, that none of these Alpine railways are calculated to supply Italy with what she really needs for political as well as mercantile reasons, viz., the most direct and shortest means of communication with Central Europe, Belgium, and Great Britain. Unlike Marseilles and Trieste, and all ports on the English Channel and the North Sea, which are all backed by railway systems, the peculiar geographical position of Italy isolates her entirely from the thickly populated, wealthy, and prosperous parts of Europe; until the Italian ports are fed by railway channels, emerging direct from Central Europe, their maritime importance must remain stagnant. Now a glance at the railway map of Europe will suffice to show that the Mont Cenis and Brenner routes are in too close a proximity to the traffic rayons of Marseilles and Trieste respectively to be of material advantage to the Italian ports; moreover, these two lines intersect territories, from which the dominions of Vittorio Emmanuele may wish for political reasons to be independent. Between the Mont Cenis and the Brenner there exists at present a break of 420 kilometres, measured in a straight line as the crow flies, or of 480 kilometres measured along the windings of the Alpine chain.

Viewing an Alpine railway as an international highway of universal importance, the geometrical axiom that a straight line is the shortest distance between two given points should be adhered to as much as practicable; any deviation from this line means loss to the producers and consumers. The shortest transit line from Northern Germany, the Netherlands, Belgium, and the Rhine Provinces, or from Eastern France and Great Britain *viâ* Italy to the East Indies and Australia, and *vice versâ*, will neither touch the regions of Mont Cenis or the Brenner, but intersect the Alps *between* the two, and go right through Switzerland. Concerning the British commerce with Italy and the Orient, it is quite evident, however, that an overland transit line can only compete with the sea route where quick and regular expedition is essential, as, for instance, in the conveyance of specie, various costly products, and raw materials. In 1861 Great Britain imported from Turkey, Egypt, the East Indies, China, and Japan, raw silk to the value of nearly seven millions sterling, and of a weight of 8,300,000 lb.; one-half of this quantity was again exported to the Continent. Now for such like fabrics the rate of freight becomes much increased by the additional item of sea insurance, amounting from one and a half per cent. to three per cent. on the value of the cargo. Viewing further the close relations between Great Britain and her Asiatic and Australian Colonies, as well as the colossal dimensions of the Anglo-Oriental commerce, there is every reason to believe that with the completion of the Suez Canal an Alpine railway through Switzerland will command more importance still in this direction, as being politically, commercially, and strategically the best transit line. Intersecting neutral territory, its safe and regular working could always be depended upon, which, particularly concerning mail service, must be an important condition.

From this point of view the Swiss Alpine passes, commanding great importance as international gateways, have been the subjects of very elaborate reports and extensive surveys; the result of these has been the advancement of three distinct projects, viz., *viâ* Simplon, Saint Gotthard, and Lukmanier. As, for obvious reasons, but one of these gigantic schemes can be carried out, they have been the cause of exhaustive commercial and technical polemics which, in their turn, represent highly interesting documents to any one connected with railways and their working, either in a financial or technical sense.*

With reference to an international transit line from east to west, as well as to the development of Swiss and Italian resources, there can be no two opinions, but Mount Saint Gotthard, favoured by its central position, stands pre-eminent among its rivals. This project, as it stands at present, involves the construction of not less than 56 tunnels of, together, 14,059 metres in length, while the great Alpine tunnel, undermining Saint Gotthard proper between Goeschenen and Airolo, is to be 14,800 metres in length, and its summit 1162 metres above sea level. The total length of the project, connecting Lucerne and Zug with Camerlata (near Como), is 265 kilometres, or 165

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* "Die Gotthardbahn in commerzieller Beziehung;" "Die Gotthardbahn in technischer Beziehung;" "Die Lukmanierbahn in technischer, commerzieller und finanzieller Beziehung;" "Simplon, St. Gotthard, et Lukmanier;" "Die schweizerische Alpenbahn;" "Le chemin de fer du Gotthard au point de vue militaire," &c.

English miles; the Alpine section, beginning at Flucleu (438 metres height) and terminating at Biasca (300 metres height), extends over 97 kilometres. The maximum gradients are to be 1 in 40, and the minimum radius of curves 300 metres (considerable difficulties being experienced in working the Semmering curves of 180 metres radius). According to the engineers of the Mont Cenis tunnel, the construction of the Saint Gotthard tunnel will occupy about 12 years; M. Grattoni, resident engineer of the Mont Cenis tunnel, calculates 10½ years, and the cost would be rather more than 2,000,000*l.* sterling; the estimate for the entire project (for a double line, but not including rolling stock) is 7,000,000*l.* sterling, or at the rate of 42,424*l.* per mile. The yearly gross receipts are calculated at 3072*l.* per mile, based upon and to be derived from the conveyance of 180,000 passengers and 270,000 tons of merchandise annually. The net earnings (the working expenses being calculated at 43 per cent. of the gross receipts) are set down at 175*l.* per mile, which would, however, not suffice to secure a fair return for the capital invested. The total yearly net earnings would accordingly be 165 × 1751 = 288,915*l.*, which sum represents 5 per cent. on 5,778,300*l.*; but since the cost of the project will be 7,000,000*l.*, subventions to the amount of 1,221,700*l.* (not counting interests during the time of construction) will be required. It is expected that such subventions will readily be furnished by the various States and railway companies interested mostly in the scheme. If this be the case, there can exist no doubts whatever in financial circles about the rentability of the undertaking, while as to its practicability from an engineering point of view, the projectors point to the very satisfactory progress of the Mont Cenis workings.

But although the Saint Gotthard project is founded on a solid basis in every direction, yet the enormous amount of capital and time required for its execution form very grave objections. These can only be avoided by making Alpine railways to climb still higher altitudes by means of steep gradients and sharp curves, and this system of Alpine railway construction was strongly advocated in 1859 by M. Eugène Flachat when the Mont Cenis Tunnel was begun. M. Flachat asserted then in his pamphlet, "De la Traversée des Alpes," that the lines should be carried *over* the mountain passes, which are in most cases situated in the region of eternal snow. The elevation of the different Swiss passes varies from 2000 to 2100 metres above sea level; to protect railway intercommunication at these heights against avalanches, snowdrifts, storms, and other characteristics of an Alpine climate, various expedients might be suggested; the present Alpine roads, for instance, are carried through covered galleries, where found necessary. From the above reports—issued on the subject of mountain railways—it appears, however, that the working expenses form the main argument of the advocates of long tunnels against surface lines. Thus the theory has been advanced that each 10 metres in height will involve an equivalent outlay in working expenses as the working of one additional kilometre on a level line. Based on this theory, the various projects have been compared with each other, as to their *real* length against *virtual* length, which latter expression means real length plus additional length (*parcours additionnels*). Although it is difficult to see how an abstract mathematical formula, having as basis only the rate of gradient, can be applied to estimate the difference in the working expenses—composed of so many distinct factors—yet it is manifest that with the present system of engines and rolling stock the economical working of Alpine surface lines would be an impossibility.

As solutions of this problem many plans, embodying distinct principles, have been suggested. While M. Flachat would apply cylinders and machinery to each individual carriage, but supply them all with steam from one boiler only, M. Thouvenot proposes to transmit power from the engine to all the wheels of the train by means of driving belts, chains, or connecting rods. Then we have Vignoles' mid-rail, as worked out by Mr. Fell, and applied over Mont Cenis. M. Riggenbach, locomotive superintendent Central Railway of Switzerland, proposes a modification of Blenkinsopp's rack rail. Further on different plans of rope traction have been suggested, among which the *locomoteur-funiculaire* of M. Agudio claims to be *non plus ultra.* A plan has also been advanced by M. Seiler, a Swiss engineer, which proposal has one cardinal point in its favour, viz., that of taking advantage of the latent power of the Alpine waters. According to his "*Balance aërohydrostatique*," a balance would be *lifted*, much in the same manner as a canal boat, and the working of the locomotive would be limited to the level sections of the line.

Your very able pen has already ventilated these systems of Alpine locomotion, which, although they lack the sanction of experience, command attention as representing the thoughts and researches of men of advanced opinions.

But, to work steep gradients economically, the question of proportion of dead weight to useful load surpasses all others in importance. With a view of reducing the former to a minimum nothing can equal the plain, practicable, and effective mode put forth by Mr. Robert F. Fairlie, C.E. His principle of creating additional adhesion simply by the paying load is worked out in the steam omnibus system in a manner which may justly be termed a very rational attempt to take the Alps, not by a long and exhaustive siege, but by a determinate, well-directed assault.

But if the former course shall be decided upon and the long tunnel line carried out, the adoption of the double-bogie system—among many other advantages—would allow the working of smaller curves (even to 60 metres radius) thereby facilitating the construction and reducing the cost of the projected line very considerably. On the principal Swiss lines the long American carriages, mounted on two six-wheeled bogies, are found to give excellent results. Now, if the principle is sound and efficient in one case, why should it not be in the other, too, and be applied to engines as well?

Yours faithfully,
ADOLPH BRUNNER.

London, April 29, 1868.

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## RAILWAY MANAGEMENT.

*From the Railway News, May* 2, 1868.

AT no time in the history of railway enterprise have questions connected with the management—that is, the actual working of our railways—assumed a greater importance than at the present moment. The state of affairs just now is most perplexing, and it behoves directors and managers seriously to consider what changes of a practical nature may be made with the view of rendering these great works remunerative to those who have embarked their capital in them. The fact that directors and shareholders should have met together recently at Manchester, to consider the present position of railway property and the means of improving it, was in itself an evidence of the necessity of some change. It was "a sign of the times" which really ought not to be overlooked. Just as in times of common danger, private and individual interests give place to considerations of public good, so was it at the conference of shareholders, and men who, on other occasions, would have been antagonistic to each other, forgot awhile their antipathies, and met for the purpose of calm and friendly discussion. It is true, as we stated last week, no practical results were arrived at. nor was there much addition made to the stock of information bearing on the subjects under consideration. The fault lay rather with the managers of the conference than with those who composed it; for the questions selected for debate were of an abstract and theoretical, rather than a practical nature. The doctors who met in consultation over the patient had not made themselves acquainted with the disease, and the remedies suggested were, as a consequence, futile and ineffectual. New forms of audit and of accounts, vote by proxy, and other matters of a similar kind, failed altogether to touch the root of the disease. The accounts, as at present prepared, show but too clearly that railways do not yield anything like the return which ought to be derived from them. Railways, as at present managed, do not pay. How to make them pay is the one great question of the day; and when once this question is satisfactorily answered, the form in which the accounts, which show the profit, is presented, is altogether a secondary and minor matter.

One point upon which we have invariably insisted in connexion with the working of our railways has been that the British public, always grumbling and never satisfied, is really too well served. The principle of competition carried to an absurd extent has ended in providing an amount of accommodation and a rate of speed of travelling for the British public far in excess of the sum paid for these conveniences. The speed of travelling on English railways is far higher, and the dividends paid are lower than those of any country in the world. It is high time that the interests of shareholders should occupy a share, at least equal to those of the public, of the attention of directors and managers. "Time is money," says the great British public. "It is the pace that kills," is the explanation that we hear at every meeting of shareholders. Surely there must be some point upon which the two opposing interests may be brought into harmony. An exacting British public has no more right to be carried on conditions which involve a loss to those who convey him, than the shareholder has to expect to be supported out of the public revenue. If time is money, the traveller who is anxious to save an hour in the run to Brighton, or two hours in the journey to Manchester, has no right to expect those who have invested in the railways to provide him with money or its equivalent out of their own pockets. We can well understand the outcry that would be raised against any attempt on the part of the so-called railway-monopolists to make the British public give value for benefits received. Everybody, we are told, must now travel by railway. True. Everybody, too, must dine. But the man who chooses a dinner at Francatelli's, with "20" port, or rare Chambertin, must not expect to feast on those luxuries at the same rate as at a shilling ordinary. So the men who prefer to travel at express speeds, who look upon time as money, may fairly be expected to pay something extra for the luxury. We are glad to see that in the bill now before Parliament for the amalgamation of the three southern lines, this principle of differential rates has been admitted. Parliament has fixed a maximum charge of fares, and a minimum rate of travelling. The South Eastern and other lines, either from a spirit of competition or from other causes, has added to the speed of the trains, and added thereby immensely to the cost of working; but though the speed has been thus increased, no corresponding advance has taken place in the fares. Under the clause as agreed to the amalgamated companies will have the power to charge higher fares for express trains—*i.e.*, trains travelling at the rate of forty miles an hour—than for ordinary trains. This is one great improvement in management, upon which railway shareholders may fairly be congratulated.

Another point, and it is one upon which Mr. Fairlie, whose letter to the *Times* we reprint elsewhere (see p. 36), very properly insists is the immense weight of the rolling stock at present in use, and the disproportion which it bears to the paying load in passengers carried. The paper lately read by Mr. Fairlie, before the Society of Arts, enters very fully into this question, and has already produced a considerable impression in the railway world. First, with regard to the engines generally in use, there can be no doubt that their weight might be considerably reduced with great advantage, for in many cases the unscientific arrangement of their parts necessitates useless additional weight for the purpose of procuring the proper amount of adhesion between wheel and rail. The non-paying load of the enormous tenders attached to express engines might be considerably lessened, and the weight of a portion at least of the water carried be brought to bear upon the driving wheels. As to the carriages, the failings of the present mode of construction are even more patent. The Metropolitan Railway is one of the most marked instances which can be taken to illustrate these. The trains on this line are mostly composed of five carriages weighing about 16 tons each, and one locomotive weighing 42 tons, together 122 tons. Thus we have 122 tons of train weight to carry an average of 55 passengers, which at 14 to 1 ton is under 4 tons, being only one ton of paying load to

30 tons of dead weight. And this disproportion between the amount of transport of passengers and the powers and capacity of trains employed in effecting it exists to a greater or less extent on all the railways of the country, and involves a loss which of itself if remedied would go far to render undertakings profitable which are now in difficulties. A comparison of a railway carriage with an omnibus admirably illustrates this position. The latter, which has to travel over an infinitely worse road than any line, weighs about one ton, whilst it carries twenty-eight passengers, or two tons, and if the horses be included, and every allowance made, the proportion will remain of one ton of paying load to one ton of material employed to convey it. This is a matter which really deserves the serious attention of railway directors and managers; for though railway carriages will always have to be more strongly constructed than street vehicles, there need not be such an immense disproportion between the weights of the two descriptions of conveyances.

Another of the evils attending the present rolling stock, to which Mr. Fairlie particularly refers, is the inefficient and thoroughly unscientific coupling arrangement. As this is at present effected, he truly observes, the result is a multiplication of the flange friction on each carriage when traversing curves, destructive to the wheels and the rails, with constant jars and shocks to the carriages due to quick starting and stopping at stations. And this remark applies still more forcibly to goods wagons, which from the less careful management of the couplings are subjected to a continual bumping while on a journey. These shocks not only cause enormous wear and tear in the wagons, resulting in a much shorter life than such solidly-constructed work should have, but are a fruitful source of damage to the freights carried. Cattle, for example, are injured; coal is reduced in bulk and value, so as to necessitate re-screening; and the milk which starts perfectly fresh and sweet is half-churned by the time it arrives at its destination. The manner in which Mr. Fairlie proposes to obviate this undoubted evil is so simple and efficient that it is marvellous that practical railway men should not have suggested and adopted it long ago. He advocates the traction of each carriage, by rods or chains attached to the under side of the framing, as near as possible below the centre of gravity of the vehicle. The ends of each carriage are to abut closely on those of the adjoining one, and are curved and arranged so as to give free play for lateral motion. The advantages of this arrangement will be at once apparent to our readers. In traversing a curve the front wheels of the carriage will no longer be forcibly dragged out of the straight course before the change of direction can affect the after ones, but the carriage being drawn, as a whole, will naturally easily adapt itself to the course of the rails. The extent of the saving of wear and tear, which would thus be effected, can only properly be appreciated by those who have carefully studied the motion of a train when passing swiftly round a sharp curve. The liability to accident from centrifugal force would be also much lessened by this arrangement, as that force is to a considerable extent neutralised as far as the whole train is concerned; and for this reason alone the system should be adopted. Compensation for accidents is a very serious item in railway expenditure; and addition to the public safety is a still higher consideration.

The matters to which Mr. Fairlie directs attention deserve the serious consideration of our railway managers. The time has gone by when stereotyped modes of working railways are to be endured, simply on the ground that they are consecrated by age and proved by experience. Railway property has got into a bad position, and it should be the wish of railway directors and managers to endeavour to find the means of making them remunerative. They cannot now recal the money wasted in litigation, and costly works, and ridiculous extensions; but they may practically effect the same object by reducing, as far as possible, the cost of working, and adopting everything which, on inquiry and careful examination, shall prove to be conducive to greater economy and efficiency. The suggestions of Mr. Fairlie are of this class; and we hope that they will receive due attention in the proper quarters.

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## REPORT ON THE FAIRLIE ENGINE "PROGRESS."

24, Abingdon-street, Westminster, S.W.,
28th April, 1868.

Robert Fairlie, Esq.,

DEAR SIR,—I have read the report on the engines sent out to Queensland, inserted in the *Queensland Daily Guardian*, dated Jan. 17, 1868.

If the reports are correct, there can be no similarity between the engines reported on and your engines when properly constructed.

I beg to send you my notes of the experiments made on the Neath and Brecon Railway March 7th of this year, at which I was present, with a party of engineers, at your invitation.

The engine experimented on, and named the Progress, was, I understand, built by Messrs. Crosse, who also built the Queensland engines.

*Memorandum, March 7th,* 1868.

Progress engine, Fairlie's patent, 44 tons loaded, on 2 bogie frames, each with 4 wheels coupled, 4 ft. 6 in. diam.
Weight per wheel 5½ tons.
Two cylinders to each bogie 15 in. in diam. 22 in. stroke.
Wheel base 5 ft.
Firebox: Grate area 21·6 sq. ft.
Heating surface 112·6 sq. ft.
Tubes No. 10 W. G., 10 ft. long and 2 in. outside diam.
Fire-box divided in the middle by "mid feather."
Train-load: 5 Empty trucks = . . . 20 tons.
15 Full " = . . . 175½ "
1 Break-van = . . . 6½ "
Gross load . . . 202 "

Distance travelled 10¼ miles.
Curves varying from 8 chains to 30 chains, and hardly any part of the line straight.
Gradients at lower part of the line varying from 1 in 60 to 1 in 66, and at the higher part of the line from 1 in 55 to 1 in 57.
Slight drizzle during the trip; the rails moist and greasy.
Steam at starting 130 lb. pressure.
Ditto ending 135 "
Time ascending 43 minutes=14 miles per hour.
Time returning 50 minutes including stoppage of train on gradient of 1 in 55, and shunting back about 500 yards, and including stoppage at a roadside station to leave three or four empty wagons, and to bring away three or four full wagons.
Motion of engine passing through points and crossings and sharp curves, with rails which were much out of line and level, remarkably easy; smoother than any first-class carriage on any line, far smoother than the break-van.
No oscillation of train from the oscillation of engine, and *therefore* no oscillation of train at all.
No deficiency of steam; some want of adhesion here and there on

the gradient of 1 in 57, and consequent slipping and waste of steam, but with a little sanding adhesion easily maintained.

Consumption of coal on the upward trip, calculated at about 9 cwt., and of water at 3½ tons—say 4 tons loss of weight on the trip—$\frac{1}{11}$th of the adhesion, which was thus reduced to 5 tons on each wheel.

The notes above are exactly as I made them, but I must add that on examining the wheel flanges it was evident that the friction between rail and flange was extremely small, as there was no sign of wearing after two years' use.

I must also add, that in running the engine backwards and forwards many times through points, crossings, and sidings, ill laid and out of order, on a very sharp curve (not exceeding five or six chains), the engine went through them with extraordinary smoothness, and I felt none of the violent blows perceptible in riding on an ordinary engine when passing through even well-laid points and crossings.

Yours truly,
(Signed) Charles Liddell.

I certify the above to be a true report of the trial at which I was present.

(Signed) James Samuel,
Civil Engineer.

26, Great George-street, Westminster.

The above report is perfectly correct, being present at the trial, and certifying to every particular.

(Signed) Alister Fraser,
Civil Engineer.

Mexican Railway Offices,
Bishopsgate-street, London.

I certify the above account to be correct in every particular.

(Signed) Wm. Roebuck, Gen. Manager,
Home Department, Mexican Railway,
Bishopsgate-street.

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*Extract from City article of the Times, April* 27, 1868.

Annexed is another letter on the subject of wasteful railway management, especially with reference to the heavy and destructive character of ordinary rolling stock, a point on which many persons hold strong opinions, pertinaciously resisted by some of the a ties most conversant with or accustomed to the existing r Unfortunately, the matter can only be fully tested by actual ment, and as changes of the revolutionary character advocated be made without expense, each company naturally hesitates to first to venture. If all the railways of the kingdom were worl a federation, recognising only mutual interests, every desirabl vation could from time to time be tried on some short selected the common expense, and with the assistance of all; but, al some approach to such a state of harmony has been initiated are yet too many symptoms that the old spirit of eager antag not only of Boards, but of the shareholders of different lines from wholly quelled, to admit of any sanguine belief that ev misfortunes thus far encountered will prove effectual for its co fulfilment:

"56, Gracechurch-street, E.C., April 25,

"SIR,—It was remarked by one of the honourable gentleme presided over the conference in Manchester that, as regarde country generally, railways had proved most successful, but t regarded shareholders, they had proved a decided failure. Nc can be more true. Yet nothing is more true than that, while rai may be made even more beneficial to the country, they can a made pecuniarily advantageous to the shareholders. The Confe however, in the multiplicity of subjects urged upon its consider missed to a great extent the great elements on which railway p depend. In this respect the only result has been the producti so much more vague discussion, and a string of resolutions on questions of a perfectly trivial character as proceeding from a ra Parliament.

"Railway prosperity, so far as the interests of shareholde concerned, depends upon two conditions only. The first is p management; the second, closed capital accounts; and in the I had recently the honour to read before the Society of A described how both these objects may be attained.

"As to closing of capital accounts, no difficulty can be experi if the management is efficient. The Conference, however, misse real point in this question. One gentleman produced a model of account, and another recommended the Indian system of a With what result? The Indian mode of audit was pronounce tolerable in England, and Mr. Watkin asserted that the pro model form of account had actually been adopted twenty year by the Sheffield Railway. The utter hopelessness of shareholders relying for profit either upon modes of audit or forms of account was, perhaps, never more conspicuously illustrated than in the case of this railway, inasmuch as it shows at this moment an entire loss of 56 per cent. of its capital. No audit, Government or other; no form of account, whether it omit or include minute statistics, can ever turn one sovereign into two. The two sovereigns must be really earned. Nor can either audits or forms of account diminish expenditure where the whole attention of the management is not expressly concentrated upon economy. If capital be closed in the mode I suggested in the paper referred to, and you trust entirely to revenue, you may keep your accounts in almost any form you please, and have any sort of audit. Dividends to shareholders are the real test whether accounts are properly kept or not. Hence the question is, in truth, mainly, if not altogether, restricted to one of management.

"In management the great evil is in the monstrous proportion of dead weight to paying load carried by our passenger trains. It amounts to between 2000 and 3000 per cent.! Every ton of dead weight costs as much to haul as every ton of paying weight. With such disproportions between the two as are now wastefully maintained the result is equal to expending 100*l.* in order to earn less than 5*l.* The constant carriage of so much dead weight is not only financially wasteful *per se*, but it is physically destructive to the stock and plant by which the 5*l.* are earned. Take the Metropolitan Railway as an example. The engines and carriages on that line are far too heavy, and if their weight were, as it ought to be, reduced by at least one-half, a saving of from 30 to 40 per cent. would be at once effected on the locomotive, carriage, and permanent way expenses of the company, while the cost of renewals of the permanent way would be reduced 70 or 75 per cent. In other words, the life of the rails would be quadrupled by the use of engines and carriages of the lesser weights named. This is purely a question of management, but it is only a part of the question. Another important part is the system of coupling the carriages together. As the coupling is now effected the result is a multiplication of the flange friction of each carriage on the curves, destructive to the wheels and the rails, with constant jars and shocks to the carriages due to quick starting and stopping at numerous stations. It would not be difficult to devise mechanical means to prevent this fruitful source of waste. Another source of waste on this line is the construction of the carriages, as well as their weight. They are mostly divided into eight compartments, and each compartment is lighted by two gas jets. There are thus sixteen jets to each carriage. If the partitions between the compartments were lowered three feet from the roof, four jets would afford sufficient light for the whole carriage, while the weight of the carriage itself would be lessened by the removal of so much of the partitions and the gas apparatus. The expenses attending the supply of twelve lights would thus be saved. Small as these matters may appear, they have an important influence upon the profitable working of the line; and they are clearly questions of management. I have referred to the existing mode of coupling carriages, and what I have said on that subject applies with equal force to the mode of coupling goods wagons. The public have but a slight conception of the losses constantly arising from this apparently simple cause. The continual bumping of the wagons against each other must have been observed by everybody. Every shock is a cause of loss or expense in some way or other, the aggregate being ultimately represented by broken coupling chains, smashed buffer heads, and damaged freights. Cattle, for example, are injured, coal is reduced in bulk and value, so as to necessitate rescreening, and, ludicrous as it may seem, the milk which starts perfectly fresh and sweet is half churned by the time it arrives at its destination. Then, as to passenger trains. Many of them earn as much as 4*l.* per mile, but the average is little more than 4s. per mile. I have no hesitation in saying that were our railways properly managed this average might be almost indefinitely increased, and a corresponding reduction made in the fares.

"These details can only be just glanced at in a single letter; but quite enough has, I think, been suggested to show that every railway, however cheerless its immediate prospects, may be rendered profitable by attention to these branches of the management. Hence lines would be extended, so that every town would have its railways, as every town will shortly have its telegraph.

"Some lessons in management may be learned from the practice on the French lines. Strict attention is there paid to little things. The pence are scrupulously cared for, and the result is that the pounds take care of themselves. Objection is sometimes taken by passengers to their being packed together as they are in France. But is the objection just? If four persons require the room provided for eight, let them have it, but not at the expense of the railway company. If they wish to travel at a speed of 60 miles an hour, by all means accommodate them, but not at the price paid for 20 miles an hour. In addition to requiring conditions so obviously just, our railway management should at once stop the running of trains that can only be run at a loss, and a debtor and creditor account should be kept of the cost and earnings of each train. Every train on the French lines is closely watched, with the object of making it productive of revenue. If a loss or absence of gain is traced to a mis-timed departure, or to local changes in the towns or districts served by any train, the train is either discontinued or modifications are made to meet the circumstances; but no train is maintained that does not contribute its proper share of profit to the whole undertaking. Why should not such a system more extensively prevail in England? It certainly demands more unity in management, closer relations between the central head and the *employés* round the circumference, and systematically vigorous control over what are now in many cases 'unconsidered trifles,' but it secures profits; and when profits are made shareholders are contented, and the public efficiently served.

"No legislation is needed to effect the mechanical and managerial improvements here recommended. The secret of railway success is with those companies who adopt them. Hence I think the Manchester Conference wasted a considerable amount of its force. The question of the continual carriage of an enormous unpaying dead weight was not, as you remarked, included in the programme. Yet on a radical change in this respect depends the future of all our railway investments. Unless the proportion of paying weight is largely raised, and that of unpaying weight largely reduced, the time must come when insolvency will be general. This impending calamity can not only be averted, but permanent prosperity insured, if we are wise in time, and readjust our management in the mechanical and traffic departments upon rational principles.

"I remain, Sir, your obedient servant,

"ROBT. F. FAIRLIE."

## RAILWAY REFORM.

*From the Mechanics' Magazine, Jan.* 10, 1868.

OWING to causes into which it is unnecessary here to enter, our railways have, during the past year, attained a most unenviable notoriety. The financial condition of many of them is at the present moment truly pitiable, whilst the whole system is in a most questionable position. Had it not been for Government intervention

during the year just closed some lines would doubtless have yie
to the pressure under which they laboured. How much longer
few others will be able to hold their own it is impossible to say.
fact, the commercial attitude of numerous lines just now is b
means calculated to inspire confidence in this class of securities,
to encourage the development of the railway system in quarters
open to the improvement it ever carries with it. Of course we
be told that railway depreciation and derangement is only part
parcel of the universal commercial convulsion which the past
years have witnessed. This is admitted; but it forms no excuse
railway defection, which might have been materially lessened, if
altogether avoided, by stricter economy in outlay, and closer at
tion to the working details of the system. Now, it is by no me
our intention to pour out lamentations for the past, nor to hurl in
tives at the heads of railway directors or managers. Such a cou
would neither be of practical value nor lead to any good result. S
ing the present condition of matters, our purpose is rather to p
out a remedy than to visit the shortcomings of officials with me
ingless condemnation—for meaningless it would be just now. A
in touching upon the matter at all we do not pretend to have
covered a perfect remedy for the general disorganised condition
railways. There are many departments in which reform is requi
that do not fall within our province to discuss. But there is
department—and that a most important one—which does peculia
belong to us to consider, and which we hope to show may be ma
rially benefited by a thorough reform, and this is the locomot
department. Of course, reform here would have a direct bear
upon the health of the whole system, which it would unquestiona
benefit in a greater or less degree.

One of the leading causes of railway depreciation is that he
item of expenditure—maintenance of way and rolling stock. T
item stands out with unpleasant prominence in every railway
count, and although the means by which it might be reduced
and have been for long past, really within reach, there is no sign
decrease, but rather the reverse. And it comes about in a v
simple way; trains are run at excessive speeds with engines un
cessarily heavy for the work they have to perform. Of course
must have high speeds for some purposes; we need not knock off
express trains, but they can be drawn by engines of lighter bu
than we are now using, and fifty or sixty miles an hour will be
readily attained. The destruction to rails and rolling stock is as t

square of the velocity, and this destruction, the bugbear of all railway accounts, would be greatly reduced by the use of lighter engines, that is of engines in which wheels are not overweighted. If instead of placing from six to seven tons on each wheel, as is at present done, not more than from three to four tons were brought to bear upon them, a great economy would be the result. Speeds should be regulated, and passengers charged according to the speed at which they travelled. With goods trains an uniform speed of fifteen miles per hour might be maintained. This is about half the present rate of speed at which these trains travel, but the compensation appears to us to lie in doubling the power of the engine, and giving them the same work to do in the same time at half the present speed. To prove that this could be done, let us suppose a thousand tons of goods requiring conveyance daily between two given points. Now, if instead of sending these in batches of 250 tons each by four trains, at the rate of thirty miles an hour, we made only two batches of them, and despatched them by two trains at fifteen miles an hour, we should effect an enormous saving. Precisely the same amount of work would be accomplished in the same period, with just half the number of trains. We should thus arrive at a reduction of risk of accident—and we all know what a fruitful source of accident goods trains are—and we should get besides fifty per cent. reduction in the cost of haulage per ton of merchandise, to say nothing of doubling the carrying capacity of the railway itself.

We have so far indicated the theory of railway reform in one important department; its practice, it must be admitted, is another matter. But we are quite prepared to prove that the course we have pointed out is not only perfectly practicable, but easy of accomplishment. This is by no means the first time we have discussed the question of railway reform; we have before debated the point upon exactly the same grounds over which we are now going. Nearly three years since, in an article upon Locomotive Reform,* we pointed out the great economy which would result from the use of engines constructed upon the very practical plan designed by Mr. R. F. Fairlie, C.E. Since we wrote, these engines have made substantial practical progress, some being in use on several lines of railway at the present time. Those of our readers who wish to investigate the details of Mr. Fairlie's engines are referred to the number of the Magazine quoted at foot. It will be sufficient here to notice the general principle of the system. The boiler is of greater length than in the ordinary locomotive, and is divided in the centre by the f box. Each end of the boiler terminates in a combustion chaml Thus there are double sets of tubes running in opposite directi from the firebox. There is also an upper series of tubes runn from the tube plate in the combustion chamber to a smoke cham placed inside the firebox shell over the firebox. The heat and p ducts from the firebox pass through the lower series of tubes to combustion chamber, returning thence through the upper series to smoke chamber, and passing out from thence through the chimn which is over the firebox shell. There is a division plate each s between the firebox and shell in the water space, reaching up to 9 above the ordinary water level, so that on going up steep gradie the tubes are not uncovered at either end.

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* *Mechanics' Magazine*, February 3, 1865.

The advantages arising from this system of construction are nun rous and important. We have first a greater generating and ma taining power than can by any possibility be obtained by the or nary system. In the next place, the whole weight of the engine, cluding fuel and water, is made available on the rails for tracti power. Tenders are entirely dispensed with, and thus an unren nerative and costly incumbrance is got rid of. The boiler bei carried on the centres of two distinct frames, each having its engin wheels, and gearing complete, made on the bogie principle, distribut the weight over the number of wheels, say four or six in each fran These being driven by their own engines act separately and ind pendently of each other, although forming but one whole. T general arrangement of the engine enables it to pass round a curves, down to a radius of one and a half chains, with t greatest facility, the friction being reduced to a minimum. Tur tables are not required for these engines, as they will run either e on. Thus upon all points this system presents important advantag and if railway companies would only avail themselves of them a litt more generally they would unquestionably find it greatly to the own interests and to those of the unfortunate shareholders.

Perhaps the most valuable testimony we can adduce upon t merits of the Fairlie system is contained in the report of Capta Tyler, the Government Inspector of Railways. The captain has ju returned from an examination of the condition and prospects of t Grand Trunk Railway of Canada, and in his able report we find hi stating that the engines which 'find most favour in Canada, an generally in America, are constructed with a four-wheeled bogi truck under their leading and four coupled wheels under their tra ing ends. And engines of this description are now being built, to weigh about thirty-two Canadian tons, for future use on the Grand Trunk Railway. The tenders run upon two bogie trucks. Six-wheeled coupled engines, such as are used in this country, are apt to leave the rails on an uneven or frozen road, and it is not safe to use them in Canada. The disadvantage of the existing pattern of the engine is, that neither the four wheels of the bogie truck, nor the eight wheels of the tender, are available for adhesion; and that, in order to obtain sufficient adhesion for heavy loads in slippery weather, a considerable weight is required upon the four driving wheels. Referring to the durability of the rails, Captain Tyler observes that it is very important to keep the weights on the wheels as light as possible, especially in cold climates, and in pointing out the means of attaining this object he says:—"The class of engine best suited to the climate, and for the various circumstances of the case, would, I have no doubt, be an engine running on two bogie trucks, each provided with a pair of cylinders, and four-wheeled or six-wheeled according to the work required—and without a tender. Such an engine would be peculiarly safe to travel over a winter road; would combine a minimum wear and tear to itself and the rails, with a maximum of adhesion, and would be the most effective and the most economical that the company could employ. I had the opportunity some time ago of testing engines of this description on the Neath and Brecon Railway, designed by Mr. Fairlie, and have found the principle to be good, though certain points of detail require improvement. Such engines are also in use for the sharp curves and steep gradients of the Queensland Railway." The points of detail referred to by Captain Tyler have been improved upon, and the principle is now as perfect as the present state of engineering science can render it. Seeing, then, that we possess, ready to hand, the means of effecting important improvements in our locomotive system, which would not only materially reduce the cost of rolling stock, but of maintenance of way, we urge upon railway officials and others interested to lose no time in adopting these means of special economy. The question is attracting much attention at the present time, and in another column we give an exceedingly well-written article upon the subject from a daily contemporary. By all means let there be unity of action in pointing out the evil, and let each do his best in his special department to aid in solving the important question of Railway Reform.

## LOCOMOTIVES IN THEIR DAILY WORKINGS.

*Extracted from Professor Mackie's Series of Articles in the Standard on the Paris Exhibition.*

The locomotive rushing along at a speed of 20, 40, 60 miles an hour is practically a huge projectile, and is subject to exactly the same laws as a cannon-shot; the damage it does is by concussion upon the rails, the force of which is divided between the permanent—or in another sense, unpermanent—way and itself. This force, like that of the cannon-shot, is estimable as the weight of the body multiplied by the square of its velocity, and the blow which the oscillations of an engine cause to be given to the rails are comparable with the impact of a rifle bolt upon an iron target. In gunnery practice the tests are generally applied direct, in railway battering the blows are indirect. The gun-shot hitting on an incline does not penetrate, but makes a more or less deep scoop, and travels on deflected from its former course. The blow is just as hard whether the thing that gives it has travelled 60 miles, 60 yards, or one-sixtieth of an inch; the actual force of impact is always given by the actual velocity of the moving body at the instant of collision. Every vertical oscillation, every lateral oscillation of a locomotive then is calculated to make the engine hit the rails with a terrible force, equalling or exceeding the tremendous blows of the largest steam hammers. Every oscillation, then, means destruction—every jolt and jar that the passenger feels means damage done to rail and engine, means so much loss to shareholders. If the blows due to velocity of impact were given direct the rails might be often smashed outright, but the main weight of the locomotive is borne on springs and carried on wheels. This, however, only modifies the evil, it does not get rid of it. The momentum is still there, and when the blow is given, although much of the violence is taken off by the springs, yet those springs give off again the force they have absorbed, and thus, although a smash is avoided, the full force of that smashing power is only distributed over such a sufficient amount of area or length of road as shall be capable of enduring it without giving way, but still, not without sustaining a considerable percentage of injury. The oscillation of the boiler is evidently thus one source of destruction, and every vibration of the springs is mischievous. For the normal load of an engine upon its wheels, 10 tons upon each axle is what is generally allowed in locomotives as at present constructed, and the deflection of a bare

¼ inch in a spring being (on the average) equal to a load of 1 ton, a depression by oscillation of 1 inch would be equal to an additional weight of over 4 tons. This extra weight, then, is, by the vibration of the springs, thrown over from side to side of the engine in travelling, gradually diminishing until the vibrations have died out. But as one set of vibrations have not ceased before another set begin, it follows that these vibrations add the equivalent of a permanent useless load upon the engine, the steam power used up in overcoming which might be usefully employed in hauling in an engine made to run perfectly stable. It is also certain that the grind upon the road must be increased by this useless swaying weight, and that bruising of the rails from end to end of the line must be done by it.

The direct force of impact of such an engine as the Stephenson's express shown at Paris, travelling respectively at the rates of 7½, 15, 30, and 60 miles an hour (88 ft. a second), would be in the proportions of 3630, 14,520, 58,080, and 232,320 foot tons, less a definite allowance in each case for gravitation, or as it would become in this case, friction, according to the actual weight of the travelling engine. In railway accidents we never see these terrific forces exerted; steam is shut off, and suction in the cylinders induced, and brakes are put on; or the blow is indirect; or the buffer springs yield; or in some way or other the momentum is seriously diminished before actual collision takes place.

Now, we do not contend for a moment that every oscillation absorbs the full amount of impact force, but there is in every oscillation a force taken up out of the momentum in the yielding parts of the engine equal to the balance between the work of locomotion done and the full power of the engine, or in other words, equal to the amount of resistance or impediments offered. Considering the enormous force contained in the total momentum of a locomotive, every small percentage even that is brought to act upon either rail or engine is a quantity whose capacity for evil needs the closest consideration from engineers, and especially as the various actions of momentum are the main source of damage to engine and rail alike, and therefore the main cause of the heavy expenses of working locomotives, and which, it is well known, now costs about 22 per cent or nearly a quarter of the gross receipts of every line. This question of damage done by neglect of steadiness in the engine—or, in other words, the cost of permitting this waste of momentum, which ought all to be employed in drawing the train, and instead goes into destruction of rails and wear and tear of engine—is one which ought to be thoroughly understood by shareholders. It is the main caus ruin to them.

Another lesson obviously comes out of the same considerat namely, that light engines and high speeds are suitable for exp trains, whilst heavy engines and slow speeds are right for he loads; or, in other words, great tractive power is the proper thing goods traffic and long passenger trains. Hence, too, we see in th rough calculations of the accelerated rates of momentum gained speeds how it is that express trains are so destructive to the roa and one can very well understand how the practical effects c covered in railway management should have produced two school engineers, one advocating light loads and quickly succeeding spatches of trains, the other long trains at long intervals carried slow speeds; the one thinking the fetch-and-carry system best, other the drag-along system the most economic. A due study of destructive action of the wasted momentum now transferred i oscillations, concussions, bruises, and friction, by practical locomot engineers will in all probability give the public the advantage of t classes of engines equally able to ply upon the same road, and equa innocuous to the permanent way; but to obtain this, steadiness the engine must be first looked to.

The question of steadiness leads at once to the consideration how the frame and boiler are set upon the wheels—the boiler bei the main mass of the engine. Set upon a pair of leading and a p of trailing wheels, with axles rigid, except in a small amount of dir vertical play, and with large driving wheels in the centre of frame, the highest forward speed compatible with the present fashi able systems of construction may be obtained; but the capability turning sharp curves is limited in exact proportion to the length wheel base—a long engine like a long dog cannot run round i small space, and short engines cannot have effective furnaces, with which effective motive power cannot be got. This difficulty bif cates in existing locomotives in two distinct directions—long engi and coupled wheels. A long engine must be set upon a short wh base, or it will not turn curves; a long engine on a short wheel b must have a lot of overhang, and must therefore be a jumpy one the direction of its onward motion. If set upon three sets of whe the tendency to longitudinal oscillation must be facilitated, beca if the centre one be a trifle too large—and can it ever be a trifle small?—the body of the engine will swing upon this fulcrum like scale beam in its hanger. Even if the adjustments be made on p fect planes in the workshop be as exquisite as the best of Stephenson's best work, there is not a yard of any railway that is absolutely level, and a hummocky rail will form a fulcrum for an engine to sway upon as well as the axle of a wheel. It is even worse, because the fulcrum being on one side, the throw of the engine will be diagonal and not direct. In the like manner the coupling of driving wheels stiffens either the whole or a large portion of the rolling gear, and the bracing of wheels together not only seriously increases friction in the proportion of the square of the number of parts coupled, but the coupling up of numbers of wheels acts against the separate play of the springs, and by increasing the rigidity of the machine accelerates the destructive action of oscillation in running in proportion as a sledge-hammer-blow character is given to the concussions. Our present 6-wheel coupled goods engines, with their enormous size and weight, must batter the roads fearfully in direct travelling if the wheel base be short, and if long, the lateral oscillations will be as great in their forward effects as the vertical ones with the short base; added to which the grind and friction must be enormous in passing curves. Now, nothing runs so easy as a thing upon four wheels, especially if the thing carried be, like a carriage, borne upon two points. If, then, we must have engines which, for the sake of tractive power or for any other reason, must have more than four wheels, the number of wheels employed should be divided into two portions, and the bearings of each portion combined at one point; the boiler, or greatest mass of the engine, should then have free play upon these two points—in fact, should be pivoted on the bearings of the leading and trailing sets of driving wheels. It is evident that if an engine run upon four wheels the whole number of wheels must always be in contact with the rails, and even if the engine were fixed together perfectly rigid, and the wheels without springs, there could be neither longitudinal nor lateral free lift of the wheels away from the rails. With a properly supported and properly balanced engine, therefore, although the permanent way was up and down like the waves of the sea, there could be no sledge hammer batter, and all the oscillations of the boiler on the springs of the wheels could only transfer the amounts of arrested momentum into additional weight brought upon the springs, and consequently grind upon the road. But the very pivoting of the greatest mass of the engine upon two points would give steadiness by its influence in preserving the centre of gravity of the boiler or principal mass from being disturbed. Another equally important object would also be thus gained, the utmost facility of passing the sharpest curves without grind against the rails the two spindles fitted to each end of the frame which support boiler, on which the bogies would pivot, would be, in fact, practi two engines, and the connecting link or boiler frame would act rope or rod to pull the wheels of the leading bogie inwards fron outer rail, against which its natural tendency would be to grind the same manner the drag of the train itself would exert the useful influence on the trailing bogie. And the value of this cu of the centrifugal force of the locomotive being inherently struc will be always in exact degree to the requirements of the occasion will be always in effect at the right moment of time.

In this way there would be the most ready adaptation of the of wheels at either end to the curves, and engines so made woul able to pass the sharpest ever put down on any line as yet constru at high speed, without danger. It will thus be seen that we disti prefer 8-wheeled engines, with the wheels coupled in two sets of each, to any 6-wheeled coupled engines which have been, or it probable can ever be, designed. We have no objection to 12-wh engines if the wheels are coupled in sets of six, each set prese the smallest practicable wheel-base, and respectively attache freely-moving leading and trailing bogies, pivoting under each of the boiler; each set also having its own pair of steam cylinder

There is another important matter to which shareholders sh give attention—tenders. The duty of a locomotive is to pull t of goods or passengers; and its capability of pulling is exactly mable by its weight and speed. It is the momentum that does motive work, and this momentum is the weight of the engine m plied by its velocity. With great steam power great momentum be worked up in a light weight by extreme velocity, and exce speed obtained; but the train-load must be light, because wit weight of engine there is not sufficient bite upon the rail to dra in other words, the gravitation of the engine is overcome and wheels slip. It is to prevent this slip that engineers have introd coupled driving wheels. They put them on to passenger engine get grip in going up inclines; they put them on to goods engin get tractive power for hauling so many more tons of coals, ston merchandise. Now the tenders are so many tons weight ha about to no purpose whatever; in short, the tender is not a hindrance but a drawback, whilst the fuel and water it has to would be doing additional momentum if put upon the engine, doi other words so much more hauling of goods or passengers along line at no additional cost whatever. No excessive weight need be put upon the wheels in consequence of the fuel load on the engine: for if to an 8-wheeled one the four wheels of the tender were added, forming a 12-wheeled engine with two sets of six wheels coupled, the weights upon each axle might be even diminished, while the whole tractive power would be increased directly by the say ten tons of coke and water, and indirectly by the getting quit of at least ten tons of load to haul in the abandonment of the useless tender itself.

Still, further, another subject comes up in these considerations, which is briefly this. That if, under the adoption of the views we have advocated, it be found necessary, as it undoubtedly would be, to lengthen the boiler, this lengthening would not be detrimental to the running of the engine, the wear of the road, nor the passing of curves, whilst the advantages would be greater generation of steam, and less liability of burning the firebox or tubes in the boiler.

The direct advantages to be looked for in the improved locomotive of the future are: That it should carry its own fuel and water, increasing thereby its hauling power without any additional expense whatever; that in so doing the weight of the engine would be better distributed over the wheels by the coupling of separate sets connected with separate leading and trailing platforms, upon the centre of which the boiler should rest, longitudinal and lateral oscillation and grind in passing curves being thus reduced to a minimum, and the present excessive wear and tear of engine and permanent way being at the same time as much as possible prevented.

The incidental advantages would be: No tenders to construct and maintain; no turn-tables to build, as such engines could run either way; less necessity in making lines of road, of reducing inclines approaching to levels; less expense in maintaining the permanent way; less interruption and less danger to the traffic in consequence of less frequency of repairs of road; less cost of maintenance of engine; and a general reduction of expenses throughout the whole of the rolling-stock and factory departments.

There was a model and plans of what seems to be such a desirable engine in the Paris Exhibition—Mr. Fairlie's. But nobody noticed them, not even those particular eminent men who have written letters to the *Times*, and had letters printed in the government report, giving their own—fortunately not the general—opinion of the advances of foreigners, and the necessity of introducing continental schools into England for the education of English engineers. The eminent foreigners who instructed them on the superior (?) abilities of foreign mechanics would not have been likely to have asked their polite attention to an Englishman's plan; though possibly at some future international exhibition we may see a French, Prussian, or Belgian engine in the aspect of continental modifications of it, and we may expect that the Playfairs of that day will then appreciate, after the explanations of their foreign friends, its especial excellences and merits.

We should regret very much being obliged to pass over the numerous models and plans shown at Paris, if we thought there was anything amongst them at all approaching Mr. Fairlie's in merit. One plan by M. Thouvenot was very like it. We do not know which was first in the field, but that is little matter, as the two plans are essentially different; that shown by M. Thouvenot being impracticable—leaving out of the question the Fell complication—while Mr. Fairlie's is thoroughly practical in all its details, and what is more, is actually at work, and therefore not problematical. M. Thouvenot's plan is still only on paper.

The designs and construction and working of the Fairlie engine have been for some considerable time past discussed in *Engineering*, the *Engineer*, in the *Railway News*, and other engineering and special commercial newspapers.

A Fairlie engine was constructed and successfully run, in 1865, upon the Neath and Brecon Line, during the construction of which it passed curves of 2½ chains radius at the rate of 12 miles an hour and to this exploit Captain Tyler has given the highest encomium, after personal experience. That gentleman has again during the present month testified to the value and advantages of the Fairlie system, in his Report upon the Condition and Prospects of the Grand Trunk Railway of Canada. We had taken our notes of the Paris model before we knew what opinion Captain Tyler retained, and indeed, as the date will show, at that time the report we have alluded to was unpublished. It is gratifying, however, to find these views so strongly supported by one so able and so experienced in railway construction and management.

The sum total of all we have to say about the Fairlie engine may be briefly enough put. It is calculated to save wear and tear of line, to haul more load at much less cost, to possess more steadiness and safety in running, to yield by its savings a considerable dividend to shareholders, to double the carrying power of every railway in the kingdom, and to reduce station expenses by doing away with costly turn-tables and their sites.

Finally, whether the Fairlie plan or any other plan in existence, or not yet in being, shall hereafter come into general practice, the point we have had at heart in these elaborate essays will have been fully attained if we can get shareholders themselves to go into the consideration of the savings to be effected by improvements in the designs of locomotives. Raising additional capital in any way must increase existing burdens; and although in some cases to capitalise floating debts may be productive of temporary and even substantial benefit, yet no permanent relief from difficulties can be afforded by any other means than increased earnings upon the lines themselves. All modifications of capital arrangements can be but shuffling the conditions like the shuffling of cards, the pack of real evils remaining constantly the same.

To make the engines of every line save in their daily working a dividend upon the outlaid capital is the one requirement to bring existing railways, despite their enormous debts, again into a healthy and prosperous state.

## FAIRLIE'S LOCOMOTIVE CARRIAGE.

*From Engineering, November* 15, 1867.

A FEW weeks ago we called attention to a system of working on heavy inclines proposed by Mr. Robert F. Fairlie, and we accompanied our remarks by an engraving of a combined locomotive and carriage prepared from designs got out by Mr. Fairlie some years ago. At the same time we remarked that Mr. Fairlie had recently paid further attention to the matter, and that he had prepared some plans which were, in many respects, improvements upon the original ones. The two-page engraving which we give herewith represents one of Mr. Fairlie's most recent designs. In our illustration, Fig. 1 is a side elevation; Fig. 2, a longitudinal section; Fig. 3 a sectional plan; Fig. 4, a front elevation; Fig. 5, a back elevation; Figs. 6 and 7 are transverse sections; and Fig. 8 is a plan showing the arrangement of the frame.

It will be seen by these views that the "locomotive carriage," as it may be termed, is carried on a pair of steam bogies, each having six coupled wheels, these bogies being connected by a frame, constructed as shown in the plan, Fig. 8. This frame, besides forming a rigid connexion between the two bogies, carries the boiler, tanks, and compartments for the passengers and goods; and the themselves are simply connected with this frame by centr check-springs being, however, provided to insure lateral stea The boiler is of the ordinary locomotive pattern, and its ba surrounded by a compartment in which goods can be stowe section of this goods compartment is given on the left-hand Fig. 6. The firing is performed in the usual way, the stoker ing behind the firebox; but the driver is provided with a raised form placed about level with the top of the firebox-casing. driver, when standing on this platform, has a clear look-out over the top of the goods compartments, the latter being kept than the passenger compartments in order to afford this clear Each bogie is provided with a pair of outside cylinders, and the s is conducted to these cylinders through pipes arranged in the manner as in Mr. Fairlie's other engines, previously described in journal.

That portion of the vehicle devoted to passengers is, together the greater part of the weight of the tanks, carried by the tra bogie, and its arrangement will be readily understood by refe to the engravings. It will be seen that there are two stories lower story or compartment affording accommodation for forty first-class and the upper story for forty-eight second-class pa gers. There are thus seats for ninety-two passengers in all. lower compartment is entered by side doors, and the upper partment by an end door, this door opening on a kind of galle which access is obtained by steps, as shown in Fig. 5. The u compartment has transverse, and the lower compartment longitu seats, and it will be noticed that the water-tank is partly sit under the central seat in the latter compartment. The other structive details will be readily understood from reference t engravings.

The "locomotive carriage" illustrated is designed for the 4 ft. guage, and its principals dimension are as follows:

| | | ft. |
|---|---|---|
| Diameter of cylinders . . . . . . . . | | 0 |
| Stroke . . . . . . . . . . . . | | 1 |
| Number . . . . . . . . . . . . | 4 | |
| Wheel-base of each bogie . . . . . . . | | 6 |
| Distance between centres of bogies . . . . . | | 20 |
| Diameter of wheels . . . , . . . . | | 2 |
| „ boiler barrel . . . . . . . | | 3 |

RIMBAULT

UNIV.
OF
MICH.

| | ft. | in. |
|---|---|---|
| Length of boiler barrel . . . . . . . | 11 | 0 |
| " of firebox-casing at top . . . . . | 3 | 9 |
| " " " bottom . . . . . | 4 | 0 |
| Width of firebox-casing at top . . . . . . | 3 | 9 |
| " " " bottom . . . . . | 4 | 0 |
| Length of firegrate . . . . . . . . | 3 | 5 |
| Width " . . . . . . . . . . | 3 | 5 |
| Width outside passenger and goods compartments . . | 10 | 0 |
| Cubic capacity of space for goods . . . . | 620 cub. ft. | |
| " " " passengers' luggage . | 87½ " | |
| " " " coals . . . . | 50 " | |
| Contents of water-tanks . . . . . | 825 gals. | |

The total weight of the machine is estimated at 54 tons, of which about 29 tons would consist of carried load, divided approximately as follows:

| | Tons. |
|---|---|
| Passengers . . . . . . | 6½ |
| Water . . . . . . | 3¾ |
| Coals . . . . . . . | 1¼ |
| Passengers' luggage . . . | 2 |
| Goods . . . . . . . | 15½ |
| Total . | 29 |

Of this carried load, 24 tons would be paying freight, and the engine would be capable of drawing after it, even up an incline of 1 in 12, a further amount of paying load, as we shall show presently.

In the article to which we have already referred, we detailed very fully the principles upon which the system of working proposed by Mr. Fairlie is based; but it will be convenient that we should repeat some of the chief points here. In working heavy gradients, it is especially desirable to reduce the dead weight of the train to the lowest possible amount, every pound of dead weight being so much deducted from the quantity of paying freight which is capable of being hauled up an incline by a given amount of engine power. Now the engine itself is as much "dead weight" as the trucks or passenger carriages, and it therefore, like them, should be made in the lightest manner possible, consistent with the provision of the requisite strength and boiler power. But, on the other hand, for working trains up heavy inclines a locomotive must possess a great amount of adhesion, and the question is how, with an engine actually light in itself, this requisite amount of adhesion can best be provided. Mr. Fell gets over the difficulty, after a fashion, by the adoption of the mid-rail and gripping-wheels; but his engines are, as we have recently pointed out in this journal, very complicated, and are, besides open to an immense number of practical objections. Besides this, the raised mid-rail is itself objectionable in a line on which many level crossings occur; and although it has been stated that on the Mont Cenis line an ingenious arrangement has been provided for lowering the mid-rail at these crossings, yet we greatly doubt whether it will be found to be of any practical use. Mr. Fairlie, on the other hand, has taken what we may term a plain common-sense view of the question, and has altogether ignored the mid-rail or any other complex contrivance for increasing the adhesion of the locomotive. Instead of these, he simply proposes to place on the locomotive a sufficient proportion of the paying load to give the engine the required adhesion, the remainder of the load being dragged behind on separate vehicles in the usual way. In some cases it may be necessary to carry the whole load on the engine, but this will of course depend upon the gradients on which the engine has to be worked. In order also to give it the requisite flexibility, Mr. Fairlie arranges his engine in the manner which we have already described, this arrangement likewise enabling him to distribute the total load upon a large number of wheels.

The advantages of this plan over Mr. Fell's will be readily understood. In Mr. Fell's engine the pressure of the horizontal wheels upon the rails adds as much to the frictional resistance of the engine as if it was carried load, whereas it is of no use except for giving adhesion. In Mr. Fairlie's engine, on the contrary, the weight which gives adhesion *is* carried load, and the additional frictional resistance which is incurred in Mr. Fell's system by placing this load on trucks or carriages is saved. Another great advantage is the perfect flexibility of the arrangement. The ngine which we illustrate this week, with its two bogies, each having a 6 ft. 6 in. wheel-base, would traverse with the utmost ease any curve which is likely to occur even on a mountain line. From the arrangement of the bogies and connecting frame, also, this shortness of the wheel-base of the bogies in no way interferes with the steadiness of the engine, whereas, in Mr. Fell's engines, notwithstanding that their wheel-base is longer, there is a great amount of objectionable overhang.

In comparing the two plans, there is another important point which deserves attention. In the case of the Mont Cenis lines, the trains which it is intended to run are comparatively light, and the engines, consequently, are of but moderate power. In the case of many mountain lines which are likely to be constructed during the next few years, however, the circumstances will probably be very different. In order that these lines should pay, there will have to be a heavy traffic carried on over them, and this will, of course, necessitate the employment of powerful engines. Now it is difficult to see how very powerful engines can be constructed on Mr. Fell's plans, unless a portion of their weight is carried on wheels which are not coupled up, and the adhesion of which is consequently not available. The Fell engine, if it is to work freely round curves, can scarcely have more than four coupled wheels, and if all the weight of a powerful engine was carried on these, the weight on each wheel would be excessive. Mr. Fairlie, on the contrary, has twelve wheels available on which to carry his load, and this number might even be increased to sixteen without making the wheel-base much greater than that of the present Fell engines.

We must now say a few words about the capabilities of the engine shown in our engravings. The frictional resistances of such an engine should not certainly be more than 18 lb. per ton, and we therefore assume that resistance in our calculations. On an incline of 1 in 12, the resistance due to gravity would be 186·88 lb., or say 187 lb. per ton, making, with the frictional resistances of 18 lb. per ton, a total resistance of 205 lb. per ton. The total resistances of the machine on an incline of 1 in 12 would thus be

$$54 \times 205 = 11{,}070 \text{ lb.}$$

On an incline of 1 in 12, also, the weight available for adhesion would be reduced to $\frac{11}{12}$ of the total weight, or to $49\frac{1}{2}$ tons, and, taking the adhesion at $\frac{1}{6}$ this weight, it would amount to

$$\frac{49\frac{1}{2} \times 2240}{6} = 18{,}480 \text{ lb.}$$

With steam at a pressure of 170 lb. per sq, in. in the boiler—and there is no reason why this pressure should not be safely carried—an effective pressure of 140 lb. per sq. in. on the pistons might be maintained throughout the stroke; and under these circumstances the two pairs of $11\frac{1}{2}$ in. cylinders, with 6 in. stroke, would give a tractive force of

$$\frac{11{\cdot}5^2 \times 16 \times 2 \times 140}{30} = \frac{132{\cdot}25 \times 16 \times 2 \times 140}{30} = 19{,}749{\cdot}3 \text{ lb.},$$

an amount slightly in excess of that which the adhesion (supposing this latter to be only $\frac{1}{6}$ of the insistent weight on the wheels) would be capable of taking up. If any objection is raised to the high pressure of steam above assumed, it might be readily met by lowering this pressure, and correspondingly increasing the size of the cylinders.

The resistance of the engine on an incline being 11,070 lb., and the tractive power (as measured by the assumed adhesion) being 18,480 lb., there would remain a tractive force of 18,480—11,770= 7410 lb. available for drawing a train behind the engine. Of the train thus drawn, the frictional resistances would probably not exceed 10 lb. per ton, which added to 187 lb. per ton, the resistance due to gravity on an incline of 1 in 12, would give the total train resistances 197 lb. per ton. Dividing 7410 lb. by 197 lb., therefore, we get 37·6, or say 37 tons, as the load which the engine could draw behind it on the incline above mentioned. Of this 37 tons, 24 tons probably might be paying load, which added to the 24 tons of paying load carried on the engine itself makes the total amount of paying freight 48 tons.

Altogether Mr. Fairlie's system has strong points in its favour, which entitle it to the earnest attention of engineers constructing or having charge of lines abounding in steep gradients or sharp curves. In India it might with advantage be adopted for working cheaply constructed branch lines serving as feeders to the main trunk railways, and it might also be advantageously employed on such a line as it has been proposed to construct in Abyssinia. In the latter instance a line, capable of being worked on Mr. Fairlie's system, might be constructed in the most rough and ready manner, the great flexibility given to the engine by the adoption of the double-bogie system enabling it to adapt itself readily to any inequalities in the road.

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## MR. FAIRLIE'S LOCOMOTIVE.

*From Engineering, May* 3, 1867.

CAPTAIN TYLER has concluded an interesting and successful trial of Mr. Fairlie's heavy four-cylinder double-bogie engine "Progress" (of which we gave a full description in January 6, 1866) upon the Neath and Brecon Railway. A train of twenty ballast-wagons, weighing, loaded, about 15 tons each, was taken several miles up 1 in 60. The engine was also run, empty, at a speed of 45 miles an hour, the motion being singularly steady, and like flying, as an engineer, who was present, has informed us. Besides Captain Tyler, the engineer of the Central Pacific Railway of California, Mr. George E. Gray, took part in the trials. Mr. Gray is a leading American engineer, and was formerly the engineering chief of the New York Central Railway. His Californian line will attain the lofty summit of 7042 ft. in a distanee of 105 miles from the level of the sea at Sacramento, much of the ascent being at the rate of 1 in 45½. It is not improbable that Mr. Fairlie's engine may be adopted upon this line, as we believe Mr. Gray has formed a favourable opinion as to its merits. Mr. Fairlie's model in the Paris Exhibition has attracted the favourable attention of many of the first engineers in France and Germany, M. Flachat having, among others, examined it with especial interest. We saw the Emperor trying its movements a few days ago, during one of his visits to the machinery gallery.

## HEAVY LOCOMOTIVES.

*From the Engineer*, *Jan.* 11, 1867.

We have had occasion to state that about 1000 square feet of heating surface appear to be sufficient for narrow gauge locomotives for working the heavy and fast traffic of the great main railway lines in this country. It must be understood, however, that plenty of water space is to be left between the tubes, and proper facilities provided for the circulation of the water; and that we do not mean to assert that engines with far more heating surface, and of far greater power, are not necessary. We speak of things as they are, not of things as they should be. One thousand feet of heating surface appear to be the greatest number that can be conveniently provided with a due regard for the foregoing conditions, and in modern practice such an area of heating surface is seldom met with in any but first-class engines. Some years ago, indeed, such an allowance was considered insufficient for first-class engines, and tubes were packed much closer than now, with, on the whole, indifferent results. The first Crampton engine put on the London and North-Western Railway, just twenty years ago, had 1529 feet of heating surfece. The cylinders were 18 in. diameter and 20 in. stroke; 229 tubes 2 in. diameter were put into a shell of moderate diameter, the water spaces being very small. This engine was equal to a load of 75 tons, at the rate of 55·4 miles an hour for a few miles, or to 55 tons at 53·5 miles an hour for a 30 miles' run; a performance which compares unfavourably with that of the Namur—built by Mr. Crampton for the Namur and Liege Railway in 1847—which had a heating surface of but 989 square feet. This engine was tested for some days in England before exportation, and was found equal to 80 tons on a level at 51 miles per hour, and 50 tons at 62 miles per hour; a duty fully equal to that of the larger and heavier engine, with one half more surface. The Liverpool had 2290 ft. of heating surface, but it is not likely that a narrow gauge engine like the Liverpool will ever be built again. Regarded as an experiment, the engine possessed some interest and attracted some attention, but the experiment was, practically speaking, a complete failure. Mr. M'Connell's narrow gauge express engine, exhibited in 1862, was probably one of the most powerful engines recently built in England. Its heating surface was 1222 ft. Only three of these engines were constructed, however, and they may therefore be regarded in the light of abnormal specimens of locomotive engineering rather than as fairly representing actual practice. The true value of heating surface is now much better understood than it was once, and we now seldom find locomotive engineers packing their boilers as full of small tubes as they can hold without bestowing a thought on the circulation of the water. The fine engines by Messrs. Neilson, which we illustrated last week, have but 867 ft. of heating surface for 16½ cylinders, 22 in. stroke, and 5 ft. 6 in. wheels. We know from practical experience that they, or more properly nearly similar engines, make an abundance of steam and work a heavy goods and passenger traffic very satisfactorily. A great portion of the goods traffic on the Caledonian Railway is worked by four coupled engines with outside cylinders, 18 in. diameter and 24 in. stroke. The heating surface in these engines is about 940 ft. only. The engines on the North London Railway, designed by Mr. W. Adams, working an exceptionably heavy and difficult traffic, have but 958 square feet of surface for 17-in. cylinders of 2 ft. stroke, and 5 ft. 9 in. wheels, the pressure being 160 lb. The narrow gauge engines of the Metropolitan Railway have 1014 square feet of surface to supply 17-in. cylinders, 24 in. stroke, with 130 lb. steam. We might considerably extend the list if necessary, but we think we have said enough to show that 1000 ft. of surface is about the most which can be advantageously put into a narrow gauge boiler. The advisability of providing more is very doubtful. Little or nothing can be gained by lengthening tubes beyond a certain point, say 11 ft. for a tube 2 in. diameter inside, and even at this the value of the last couple of feet is very small indeed. Four feet, or 4 ft. 2 in., is the greatest diameter admissible on the narrow gauge, and 160 2-in. tubes are quite enough to pack into such a barrel. Nothing will be gained by using more. How, then, are we to obtain greater boiler power on the narrow gauge?

For the last two or three years Mr. Fairlie has been labouring to produce a design for a locomotive of maximum power, which shall at the same time prove economical in fuel and exceptionably light upon permanent way. Several of these engines have been constructed by Mr. Cross, of St. Helens, and the design has already been so fully described in our pages that we feel certain most of our readers are more or less familiar with its characteristics. The boiler extends both ways from a central fire-box, and is supported at each end on a bogie carried by four or six wheels, coupled, and propelled by a pair of cylinders; the engine having thus four cylinders in all. The system has, in a somewhat different shape, been already tested very successfully on the Sëmmering incline, so that it can no longer be regarded as an untried novelty. In such a design we at once find an answer to the question, How can more surface be advantageously provided in a narrow gauge boiler? The merits and demerits of Mr. Fairlie's engines have recently attracted a good deal of attention among engineers, and a great deal has been both said and written on the subject. As is often the case, however, both the advocates and opponents of the system have almost totally overlooked the real points at issue, and have nearly confined themselves to discussing the question, Do we or do we not require more powerful engines than are at present in use? It is obviously quite hopeless to expect anything like unanimity of opinion on such a subject as this. Every locomotive superintendent will speak according to his own experience and the conditions of traffic with which he has to deal. In point of fact, it is a subject which hardly requires discussion at all. It is beyond all question, we think, that heavier engines than those now employed might be used with advantage on most great lines if that use could be rendered compatible with anything like permanence in "permanent" way. We do not say that heavier engines are absolutely required to work the existing goods traffic of the London and North-Western, Great Northern, or, in short, any other line either in England or abroad. Indeed, we feel certain that the use of engines carrying a greater weight on each pair of wheels, would be found anything but economical. In the first place, it is not easy to see how more heating surface could be provided with advantage. By using small wheels the diameter of the boiler might be increased, it is true, but pressure must then be reduced, or the weight of the boiler and its first cost greatly increased. If pressure is kept down, the diameter of the cylinders must be increased, aud every locomotive engineer knows what that means. In the second place, increased weight would simply mean increased wear and tear of permanent way. We have no reason, then, for saying that, under the circumstances, the present policy of locomotive superintendents is not prudent and consistent, to a certain point, with the interests of shareholders. But we may be allowed to point out that their practice is only right in one sense, because it is not right in another. It is right, because they confine themselves to the use of engines of a stereotyped pattern; but it is not right that such a pattern should be regarded as the *summum bonum* of railway practice. Our neighbours in France have long since struck out a line for themselves, and M. Petiet's great engines on the *Chémin du Fer du Nord* have enabled that gentleman to work a tremendously heavy traffic with great certainty and with a considerable saving. We cannot blind ourselves to facts, nor should we be ashamed to learn even from our neighbours. Steel rails and steel tires are not able to combat successfully the destructive influences brought to bear on them, and we are disposed to think that there are but few lines in this kingdom on which the ordinary pattern of goods engines might not be experimentally departed from with a prospect of advantage.

We do not wish, as we have said, to argue the question as to whether heavier engines are or are not required. We believe that they would prove at least as efficient here as on the Continent. This is scarcely a matter of opinion, but it unfortunately borders so nearly on the theoretical, that we shall not now press the point. But there are other features connected with Mr. Fairlie's engines which are in no way matters of opinion, but essentially matters of fact. The greater the load we place on a railway wheel, the greater the injury done to permanent way. Not the rails alone, but the chairs and the sleepers suffer from the rolling impact of heavily loaded wheels. The longer the wheel base, the more is the evil augmented. All this is an old story, on which we need not dwell; but why should not the story narrate truthfully what is now, as well as what is past? When the engineer finds his bearings heating and cutting, notwithstanding that they are well lubricated, he knows that the surface is too small. Our rails cut and wear for precisely the same reason—the bearing surface is too small; and it does really appear that here Mr. Fairlie has shown us the way out of a great practical difficulty. The only available method of increasing the bearing area of wheel and rail is to increase the number of wheels. But more than six wheels cannot be advantageously coupled; and as it is, an inflexible base three wheels and a fire-box long, is enough for any curve but the very easiest. In the Fairlie engine the wheels are arranged close up in swivelling groups; and four cylinders being employed, not only is the coupling difficulty overcome, but that connected with curves as well. Certain objections may, no doubt, be urged against such an abnormal design, and it has been said that two engines coupled foot-plate to foot-plate would answer better. But exception may he taken to any locomotive ever designed; and we are not aware that Mr. Fairlie's most vigorous opponents have been able to dispute that his engines would be exceedingly light on permanent way, and competent to make more steam than any ordinary narrow gauge engine of reasonable dimensions which can be built. As to the second point, it is sufficient to state that the plan of using Siamesed engines has been thoroughly tested, and completely failed. An immense amount of labour and ingenuity might be, and possibly will be, expended in finding all sorts of theoretical objections to any new design of locomotive which may be brought forward; but such discussions serve no good purpose whatever. They do not increase our stock of information, and they do not promote the advancement of science. It is known that existing types of locomotives are injurious to permanent way because the weight on the wheels is too great and the wheel base too long. It is known that in France heavier engines than any we use are employed with advantage. It is certain that on many English lines greater locomotive power might be used with benefit than can now be had. Mr. Fairlie has not only proposed, but actually built engines which depart widely from existing models, but which, nevertheless, are free from the objections which can be urged against these models. Therefore, under the circumstances, his designs and his opinions are well worth the most serious attention of those who are interested in the cheap working of railways, and it will be matter for regret if any spirit of conservatism prevents Mr. Fairlie's engines from having that extended practical test which can alone decide in what the real merits and the real defects of the design reside. The questions at issue cannot be solved by newspaper discussion, but it is evident that if the design possesses one-half the advantages which its originator claims for it, and which apparently it really presents in a great degree, nothing could possibly be lost by its adoption on probation by several English lines working a heavy goods and mineral traffic. It places at our disposal the means of doubling heating surface and steaming power without packing tubes too closely or increasing the diameter of the boiler beyond 48 in.; it enables all the weight to be used for adhesion; it dispenses with the separate tender, saving thus from seven to ten tons of dead weight; it enables the sharpest curves to be traversed with the utmost facility, still keeping the centre of tractive effort inside the curve; it provides the means of coupling twelve wheels without extra frictional resistance; it distributes the load over a large area, and the weight is so arranged that great running steadiness is secured. All these are indisputable advantages, which cannot be realised on any other system with which we are acquainted; that such advantages do belong to the design is simply incontrovertible, and they entitle it to as much consideration as any other design has ever merited since the days when George Stephenson built the Rocket.

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*From the Times, Jan.* 10, 1867.

As regards the locomotive engine, there is still a manifest tendency to build larger and larger engines, and, we are happy to add, to adopt systems of construction which will spare permanent way. The bogie is now more freely adopted in England and by English engineers carrying out designs for locomotives to be used abroad than was once the case. Mr. Adams's radial axle-box also is now undergoing a very complete test on the Great Northern, and London, Chatham, and Dover Railways, where it is giving very favourable results. But the system which of all others holds out most promise of ultimately rendering the use of engines of maximum power compatible with moderate expenses for the maintenance of way, is that introduced in this country by Mr. R. F. Fairlie. Engines constructed on this system, now too well known to need particular description, have already given excellent results under very unfavourable conditions in Wales and elsewhere, and we believe that Mr. Fairlie is now designing an improved type of engine from which still more may be expected. We cannot here consider the important questions involved in a wide departure from normal methods of construction such as this, but we may state our conviction that Mr. Fairlie's ideas appear to be full of promise, and that we have no doubt important progress will be made in this direction during the year. In the minor details of the locomotive there is not now much room for improvement; if we except, perhaps, arrangements for burning coal without smoke, which are still very imperfect. Our German correspondent has recently explained how great is the progress made by continental engineers in adapting the locomotive to the use of a wretched coal, at which the English driver would "cause himself to turn up the nose of contempt." It is evident that it is possible to use cheaper fuel than that which we now employ, excepting, perhaps, in our express and mail service, and there is no good reason why English engineers should not follow the excellent example set them by their continental brethren, and endeavour to reduce annual coal bills and increase dividends.

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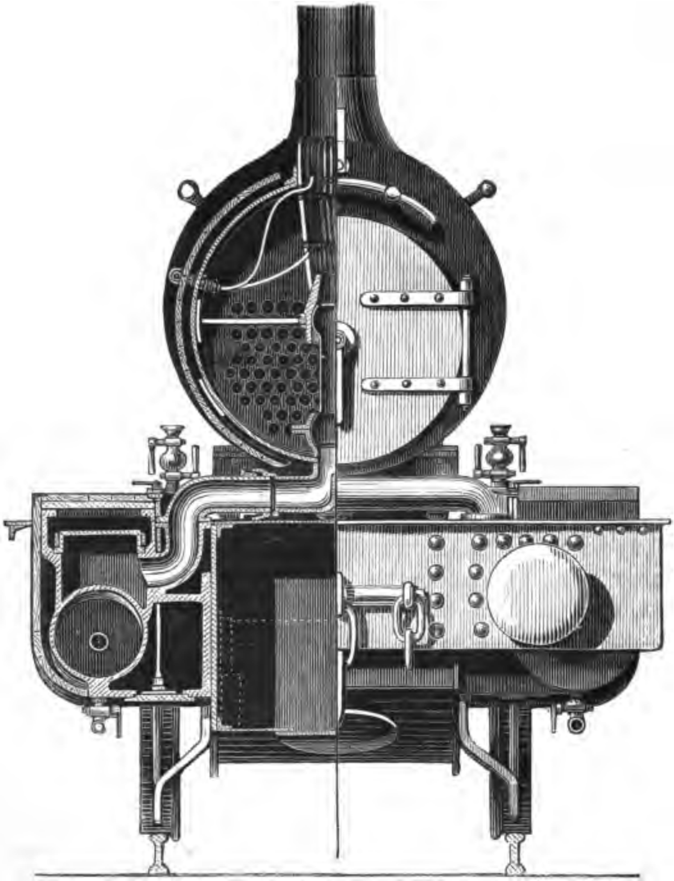
# LOCOMOTIVE ENGINES FOR THE SOUTHERN AND WESTERN RAILWAY OF QUEENSLAND.

*From Engineering, Nov.* 30, 1866.

Some weeks ago we gave, in this journal, an account, with illustrations, of the carriage and wagon stock for the Queensland Railways, and we then mentioned the peculiarities of construction, which the narrowness of the gauge of those lines—3 ft. 6in. —had rendered necessary. As we then stated, there are two lines in Queensland, namely, the Southern and Western and the Great Northern Railways, to both of which Sir Charles Fox and Sons are the engineers; and we now present our readers with engravings of some 12-wheeled coupled engines built by Messrs. James Cross and Co., of St. Helen's, for the former line. These engines were designed by Mr. Douglas Fox, and they are arranged on the system patented by Mr. Robert F. Fairlie, to which we have frequently alluded in this journal.

As will be seen by the views given on the large engraving, the wheels are arranged in two groups, three pairs in each, the wheels forming each group being coupled together, and driven by an independent pair of cylinders. The diameter of the wheels is 3 ft., and the three pairs forming each group are placed at equal distances apart of 3 ft. 3 in. from centre to centre. The distance between the centres



of the groups is 16 ft., so that the total wheel base is 22 ft. 6 in. The tyres are of steel, spring seated on Mr. W. B. Adams's patented plan; and those of the middle pair of wheels of each group are without flanges.

The cylinders are outside, and are 11 in. in diameter, with a stroke of 1 ft. 6 in. They are fixed in a slightly inclined position, 5 ft. apart transversely from centre to centre, and have the valve chests on the

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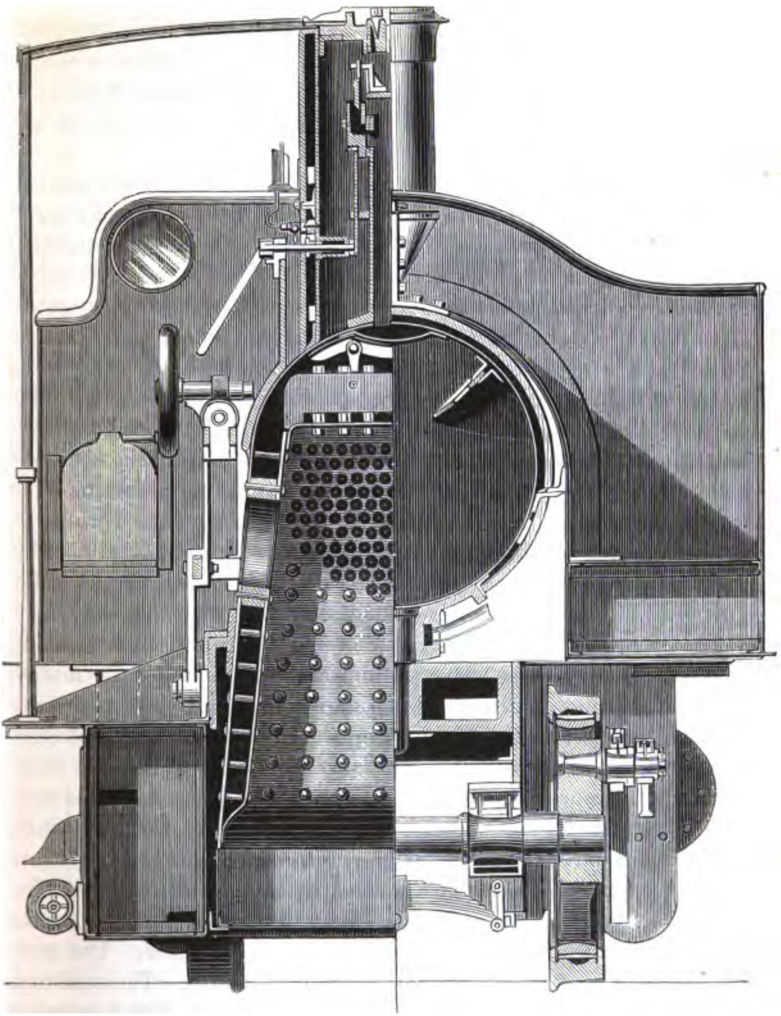

top of them, as shown by the transverse section through the smokebox, given on the opposite page. The pistons are of cast iron, fitted with Ramsbottom's rings, and the connecting rods are coupled to that pair of wheels of each group which is furthest from the cylinders, so that a good length—6 ft. 2¾ in.—is obtained between centres. The main frames of each bogie are rather close together, even when the narrowness of the gauge is taken into consideration, the distance transversely from outside to outside being only 2 ft. 7½ in. At that end of each bogie which is next the firebox the main frames are connected to the arched transverse plate carrying the curved slides by which each bogie frame is coupled to the frame extending round and supporting the firebox, as in other engines constructed upon Mr. Fairlie's system.

The axle bearings are, like the frames, placed rather close together, the transverse distance between centres being 2 ft. 2 in., and a space being left between the outside of each bearing and the corresponding wheel boss. The object of this arrangement appears to have been to get the eccentrics outside the frames. The chief bearing springs are all of the transverse kind, and are placed one below each axle, as shown in the engravings. As springs so arranged would give no lateral stability, each bogie has been provided, in addition, with four volute springs—a pair near each end—these being placed between brackets fixed to the inside of the main frames and brackets on the boiler. This arrangement is shown in the front elevation. The transverse distance between the centres of these volute springs is, however, only 2 ft. 1 in., so that the spring base is very narrow. The axle-boxes are of cast iron, with brass bearings, and all the axle-box guides are fitted with adjusting wedges.

The eccentrics are, as we have already stated, fixed on the driving axle outside the frames, close to the wheel bosses; the valve motion is of the shifting-link kind, and motion is communicated to each valve through the intervention of a rocking shaft. The reversing is effected by means of a screw, and the gear is so arranged that it is not influenced by the movements of the bogies. The engines are fitted with injectors arranged horizontally, one outside each of the side tanks, and the feed water is carried partly in tanks fixed between the frames under the barrels of the boiler, and partly in side tanks situated beneath the footplate on each side of the firebox casing, and on the footplate on each side at the bottom of the coalboxes. The combined contents of the tanks amount to 1030 gallons. The coalboxes are four in number, and are placed one on each side of each barrel of the boiler, near the firebox casing. They have an aggregate capacity of 120 cubic feet.

The arrangement of the boilers is clearly shown by the half longitudinal section given on the large engraving. It has two barrels and a central firebox, the former being each 9 ft. 10 in. long by 3 ft. in diameter inside. The firebox casing is 6 ft. 3 in. long, and its width tapers from 3 ft. 9 in. at the bottom to the diameter of the boiler at the top, the latter being flush with the barrels. The inside firebox has a surface of 72·1 square feet, and its top is stayed by transverse roof stays, assisted by sling stays, as shown in the figures. The firegrate area is large—17·4 square feet—so that wood can be readily burnt, and the firing is performed through doors at the sides of the firebox. Each barrel of the boiler contains 133 tubes, 1½ in. in diameter, these giving a heating surface of 1037·4 square feet, and making, with the firebox surface, the total heating surface 1109·5 square feet. As the great length of the boiler would render longitudinal stays somewhat inconvenient, each of the smokebox tubeplates is stayed by gusset stays, as shown in the longitudinal and transverse sections.

The boiler has a dome fixed on the top of the firebox casing at the middle of its length, and in this dome is placed the regulator which governs the supply of steam to both pairs of cylinders. The regulator is of the gridiron class, and from it the steam passes into a pipe formed by rivetting a bent plate along the inside of the top of the boiler for a considerable portion of its length. We cannot say that we like this arrangement, as the tightness of the pipe, of course, depends upon the tightness of the rivetted seam along each side of the bent plate, and any leakage through this seam would, of course, admit steam to the cylinders, and might occasion much trouble. From the pipe or passage along the top of the boiler the steam passes into a couple of small steam chests placed one on each barrel, and from these it is conducted by branch pipes to other chambers, fixed one on the bottom of each barrel, these chambers being annular, and forming the sockets into which the bogie pins are fitted. From each of the annular chambers a forked pipe conducts the steam to the cylinders, this pipe being connected with the chamber by a stuffing box, which allows the pipe to follow the movements of the bogie to which it belongs without being strained. The blast pipes are also arranged so that they can follow the movements of the bogies, and at the same time deliver their jets in the centre of the chimneys, the the arrangements of ball-and-socket joints adopted being clearly shown in the longitudinal and transverse sections. Each barrel of the boiler is furnished with a manhole at the top near the smokebox end; and we observe that these manholes are merely strengthened by a ring rivetted round each of them on the inside, but are without mouthpieces.

The weight of each of these engines is 30 tons, this weight being equally divided, 2½ tons on each wheel. They are intended to draw a load of 120 tons, including their own weight, up a gradient of 1 in 45, 12 miles long, and it is probable that they will be found capable of performing a still greater duty. The line on which they are to be worked has frequent curves of 330 ft. radius, and it is probable that curves of still smaller radius will be introduced, and around which the system upon which the engines are constructed will enable them to pass readily and safely. We shall not speak further respecting the capabilities of these engines at present, but we may mention that in the course of a paper by Mr. Douglas Fox, read before the Institution of Civil Engineers on Tuesday last, the author stated that each of these engines was capable of exerting about twice the power of each of the tender engines previously made for the Queensland lines, whilst the cost of the two classes had been 2500*l*. and 1850*l*. per engine respectively.

## LOCOMOTIVE ENGINES.

*From Engineering, November* 9, 1866.

A REVOLUTION must yet take place in the construction of locomotives hardly less complete than that which we have witnessed in ships of war. When engines, a few years ago, were occasionally made to weigh 25 tons, there was a great outcry as to the excessive strains which they put upon the way. But we were never increasing the weights of engines more rapidly than now, and there are already two eight-coupled engines on the Great Northern line, and others on the Vale of Neath, which weigh each 56 tons. The North London and the Metropolitan passenger engines weigh 42 tons, with 30 tons on the four coupled wheels, and it is clearly apparent that heavier and heavier engines will yet be required for all the great main lines. Upon the present plan we cannot greatly increase the power of the boiler. Its diameter is already as large as the room between the wheels will admit. It is of no use to greatly increase the length of the tubes. The heating surface thus gained is of very little value, and extra strength of blast is requisite to pull the gases through under the increased tube friction. Even for a mechanical reason long tubes are objectionable, as they are apt to sag and work loose in the tube plates. A very large firebox, without increased tube surface, is also of little use. The French engineers have met the question of larger engines in a bold and even ingenious manner, as illustrated in M. Petiet's engines, engraved in our last number. But here there is a good deal to object against. To clear the wheels, the firebox and boiler are placed entirely above them, and thus almost any width of grate and any diameter of barrel may be had. But the result is a mountain of machinery 12 ft. high, and liable to roll heavily and dangerously at moderate speeds. Again we are still increasing the working steam pressure. Steam of 160 lb. is regularly carried on several lines, and new engines for one of the great metropolitan lines are being designed to work at 180 lb., and, possibly, 200 lb. Very large barrels are hardly compatible with great pressures. Then there are objections to the mode in which the French engines are carried; for, whether they have ten or twelve wheels, the axles are parallel, and the engine must strain the line in moderate curves. We are not objecting to their four cylinders and double sets of driving and valve gear, for we doubt whether the great tractive force we have considered can be so well obtained with two cylinders as with four. Great steam tractive force corresponds to great adhesion weight, and unless the weight be excessive, say 8 tons to 10 tons upon a single wheel, this can only be utilised by coupling or by additional cylinders. The objections to coupling eight wheels together are manifest, although it is often done on the Continent and in the States, and occasionally in England. Indeed, one engine has been constructed in the States with twelve coupled wheels, all worked by a pair of 20 in. cylinders. With a single regulator and reversing gear, we believe there need be no objection to four cylinders upon a locomotive, and we hear no complaints upon the score of complication in the case of the four cylinder engines now fitted to twin-screw steamers.

Mr. Fairlie has grasped the whole subject of heavy locomotives in a sensible and practical manner, and we learn that, in addition to those he is already working, he is designing one of 72 tons weight, which is to be built with the expectation that room will be found for it in the Paris Exhibition. By his plan of double bogies of coupled wheels, each driven by a separate pair of cylinders, he not only distributes the weight of the engine, however great, upon eight or twelve points, as required, but he obtains great ease of working around very short curves, the governing wheel base being that only of each bogie, which need measure but from 5 ft. to 10 ft., according to the size and number of the wheels. As the firebox comes entirely between the bogies, it may have any width required, up to 7 ft. or 8 ft., if such a width were necessary; and as the boiler has two barrels, a vast extent of effective tube surface is obtained with a moderate diameter of boiler. In the case of the proposed new engine, with four cylinders

18 in. in diameter, for 24 in. stroke, and having two bogies, each with three pairs of 4 ft. coupled wheels, the firebox is to be 12 ft. long by 4 ft. 6 in. wide outside, with grate-bars sloping down each way from the centre, where it is fired, and the two barrels, each 4 ft. 4 in. in diameter, are to have together 408 tubes 2 in. diameter and 11 ft. long. The centre of gravity of the whole engine is low, and the foot-plate will be on the top of the firebox. In all its broader features the system appears to be that upon which all very heavy engines—and such engines are now more and more in request—should be constructed. The plan involves, however, important points of detail. The steam is to be taken through the bogie centres, and here stuffing boxes are necessary, although the motion will not amount to the one-hundredth part that of the trunnions of an oscillating engine. The bogies, furthermore, will be connected, as in all Mr. Fairlie's engines, by a framing through which to transmit the pull of the engine, without straining the boiler; and not only must this framing accommodate the pivoting motion of the bogies, but it must also directly bear a share of the weight. The success of the system will turn, we think, upon the strength, simplicity, and durability of the framing. We need not here describe it, as we have illustrated it in a former number of this journal. It certainly is less simple than the ordinary construction, and it presents points upon which questions might be raised as to fitting and wear. But we hear that the quadrants, and their sliding blocks which connect the two bogies in one, have answered well in use: and it is clear that, should they fail to give satisfaction, a continuous framing might be employed to connect the bogies by their centres, and to transmit the weight to the centre of one bogie and to the sides of the other, thus carrying the whole upon three points, as in the North London and in all American engines. There need be no fear of applying the whole pull of one pair of cylinders through a properly made bogie centre. The continuous framing might be made to give great longitudinal support to the boiler, even if it did not distribute the weight at any point intermediate between the centres of the bogies. We have known very long fireboxes to be wholly unsupported by the framing, and to remain tight and strong; and we can see how a boiler made as in Mr. Fairlie's design might be supported without any undue strain upon two points 20 ft. apart. We have touched upon these few points of detail, not from any doubt that the principle of the double bogie engine may be worked out in the most complete and successful manner, but because they are in any case of great importance, and

because even further improvements may probably be made in the plans, which, as now carried out in practice, give so much promise of good results.

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## THE QUEENSLAND RAILWAYS.

*From Engineering, August* 10, 1866.

THE gauge of the Queensland Railways, as many of our readers are aware, is but 3 ft. 6 in. It has steep gradients, one of twelve miles, rising 1 in 45, and there are frequent curves of 330 ft. radius. The engineers of the line, Sir Charles Fox and Son, have adopted Mr. R. F. Fairlie's plan of engine, with two bogies of six coupled wheels each, or twelve wheels in all. These engines will have two pairs of 11 in. cylinders and 18 in. stroke, the wheels will be each 3 ft. in diameter, the total weight will be about 30 tons, corresponding to 2½ tons per wheel, and the total wheel-base will be 22 ft. 6 in. They are to draw 120 tons, including their own weight, up the twelve-mile gradient of 1 in 45, and we presume that they will be found equal to a still greater load. Messrs. James Cross and Co., of St. Helen's, and Messrs. Neilson and Co., of Glasgow, are the makers of the engines, and the carriages are in course of construction by the Ashbury Carriage Company, of Openshaw, Manchester. We hope shortly to present drawings of this unique rolling stock to our readers.

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## MR. FAIRLIE'S LOCOMOTIVE.

*From Engineering, August* 10, 1866.

THE engine Mountaineer, tried by Messrs. James Cross and Co. at St. Helen's, on Thursday week, was of the pattern illustrated and described in *Engineering* of March 23rd last, page 180. It had two pairs of 10 in. cylinders (equal to a single pair of 14¼ in. diameter), 16 in. stroke, two bogies of four coupled wheels, each 4 ft. in diameter, an extreme wheel-base of 19 ft. 11 in., and weighed, loaded, about 34 tons. The wheel-base of each bogie was 4 ft. 11 in. The two barrels of the boiler contained in all 804 square feet of tube surface, while the firebox surface was 54 square feet, and the area of the grate 12½ square feet.

The engine was run to the bottom of the St. Helen's bank, which for several miles averages 1 in 80, one portion being as steep as 1 in 65. At the bottom of the incline it was attached to a train of fifteen loaded coal wagons, loaded to 10 tons each, or 150 tons in all, and a brake van, the total weight, including engine, being 194 tons. The pressure of the steam was 130 lb. on starting; but this fell off very considerably as the engine went up the bank, but about 80 lb. having been left at the top. The speed up was, for part of the way, 24 miles an hour, falling off, on the steeper portion of the incline, and with a diminishing pressure of steam, to 13 miles. The resistance of gravity, of a weight of 194 tons, upon an incline of 1 in 80, would be 5432 lb., while the total steam tractive force of the engine, with 100 lb. mean effective pressure, would be 6667 lb. only; and as the total rolling resistance and engine friction cannot well be estimated at less than 10 lb. per ton, it would appear that a mean cylinder pressure greater than 100 lb. was maintained, the pressure corresponding to the estimated gravity and train resistance being 110½ lb.

The observations were not made, however, with that degree of care which would give entire precision to these results; but there was no doubt that the engine did her work very well, with the exception only that the supply of steam was insufficient. It will doubtless be found desirable, in further engines upon this plan, to make a separate firebox to each barrel, and to somewhat enlarge the present grate area. The utmost steam tractive force of the engine would be hardly more than one-tenth of her total weight, and thus, although the weight on each wheel did not exceed 4¼ tons, there was a great proportion of adhesion weight to steam force. And at the same time the wheels can easily traverse the shortest curves, the governing wheel-base being that of each bogie, or 4 ft. 11 in. only. The engine worked with the utmost steadiness, as was to have been expected from its length, and from the fact that with four cylinders the strains tending to cause either sinuous motion or rocking are but one-half as great, at a given point, for a total given power, as would be the case with but one pair of cylinders. The trial on Thursday week was attended by Lord Richard Grosvenor, Messrs. Henry Maudslay, Walter M. Neilson, George England, Mr. Holt, locomotive superintendent of the Neath and Brecon Railway, and upwards of a dozen other gentlemen interested in the trial.

## HEAVY PASSENGER LOCOMOTIVES.

*From Engineering, April* 20, 1866.

Sir,—In your impression of April 13th, you give some statistics of the power and weight of the ordinary type locomotives that will be required for working the passenger trains on the Metropolitan and St. John's Wood Railway from Baker-street to Hampstead, and while endorsing every word you have written as to the power required for working this line, I hope you will not consider it out of place if I mention a few particulars of my patent engine, lately illustrated and described in your paper, and compare its power with the 55-ton engine you propose for the line in question, to work which efficiently under the conditions mentioned, three distinct essentials are requisite, namely, great generating power, great cylinder power, and great adhesive power, and I may also add a fourth, namely, the power of passing round the sharpest curves without any appreciable extra friction.

My saying that I believe it is almost impossible, consistently with any degree of economy, to obtain these four conditions with the ordinary type of locomotives, is perhaps what might be expected from one who is advocating a new system. At the same time feeling strongly that my engine contains every one of these essentials, I ask to be permitted through the medium of your valuable and influential paper to endeavour to prove this; but while doing so argumentatively, I rely solely on actual experiment to bear out every assertion I make.

In the first place, generating power. No one will, I think, dispute that the power to generate steam, with two barrels and two sets of tubes, each leading in opposite directions from a central firebox, must be greater than with the ordinary single-barrel boiler, it being a well-known fact that the steam-generating power of tubes is more than twice as efficient within three or four feet of the firebox than all the rest of the tube surface, no matter of what length. Besides these advantages, I get nearly double the capacity of boiler power for supplying the necessary quantity of steam to cylinders of large dimensions.

Again, with this system of boiler the weight always remains in the same proportion on each wheel, no matter how the total weight of the engine is altered by the consumption of water and fuel. It is admitted that the pressure in the boilers of the Metropolitan engines, considered the best and most powerful engines of the day, becomes reduced to 70 lb. per square inch, resulting most decidedly from incapacity of boiler power. The simple fact being, the cylinders use a greater quantity of steam than the boiler can supply, consequently the pressure of steam must get reduced in proportion as the supply falls short of the demand.

Secondly, great cylinder power. By the use of four cylinders I can practically obtain any amount of tractive force that is ever likely to be required on railways, which is next to impossible with existing locomotives, from the great difficulty which must exist in fastening securely two cylinders of large diameter to the framing. Add to this the great strength and consequent weight on the motion parts of a locomotive with cylinders of a large diameter.

Great adhesive power. This is another point in which I consider there is a great superiority in the principle I advocate over the present system. Is it not an indisputable fact that the entire system of railway construction in this country is made subservient to the locomotive alone, and not by the traffic on the line? Why should this be so? The answer is simple enough. If we must take loads, we must have adhesion on the rails, and to get adhesion we must put weight on the wheels. I will not take up your valuable space by an argument on this point, which to many would appear reasonable enough. (This question will be found fully discussed, and, I think, settled in a little pamphlet written on the subject of my patent locomotive some time ago, and which I shall be happy to send gratis on application to any of your readers interested on this subject.) But it is an unsound reason. I maintain and can prove that any amount of adhesion can be obtained without in the least damaging the permanent way, to keep up which, under this most injurious system, a large portion of the dividends that ought to go into the pockets of the shareholders is applied, and which little fact should receive their earliest and earnest attention.

Take, for instance, the amount of adhesive force you very properly state will be required to perform certain duties on the line in question, viz. 42 tons on six wheels, giving 7 tons on each wheel on a base of not more than 9 ft. 6 in. or 10 ft. One has only to imagine 42 tons ploughing along on a base of 10 ft. to give some small idea of the immense wear and tear to the permanent way which must follow; neither must it be forgotten that there is, besides these 42 tons, a bogie-frame and four wheels, weighing 13 tons, perfectly useless, except for supporting the leading part of the engine; and when taking the figures you have given, viz. that three carriages weighing 45 tons, and 15 tons passengers, will be as much as the engine can take on an incline of 1 in 27 up to Hampstead, it follows that the 13 tons useless load of the bogie becomes a very serious item indeed, being within 2 tons of the total load of passengers, from which alone revenue is derived. In my system, as you are aware, there is no useless weight, every pound weight being available for traction.

As regards the question of passing easily round sharp curves, I consider I need not enter into this matter, but to quote a very old saying, "The proof of the pudding," &c., is the best sort of argument. I beg you will do me the favour to publish with this communication a letter I received this morning from Mr. John Dickson, the contractor of the Neath and Brecon Railway, who has had one of my medium-sized patent engines at work for some time. It is sufficient to show that a 2½ chain curve on an incline of 1 in 30 is daily worked at the ordinary speed with perfect ease, and that fifteen trucks (remember, on a new line), weighing 190 tons gross, with the ordinary lever brakes on each truck, and each brake down, could not stop the engine up an incline of 1 in 50.

All theories vanish before these two simple facts of actual work done; they speak for themselves on every point I have mentioned as necessary in the locomotive engine.

The small contractor's engine, called Mountaineer, Mr. Dickson speaks of as taking 170 tons up a long gradient of 1 in 70. She has four cylinders, 10 in. in diameter, 16 in. stroke, eight wheels 4 ft. in diameter, weighing, in working order, 22 tons, or 2¾ tons on each wheel, being actually less than the weight on an ordinarily-loaded wagon-wheel.

Robert E. Fairlie.

**56, Gracechurch-street, London, E.C.**

"Dear Sir,—I am in receipt of your letter of the 16th, and in reply to your inquiries respecting the 'patent' engines, I cannot but express my belief that they will do all you have led me to expect. I have not put them to any severe trial, having had no occasion to do so; but it may be satisfactory for you to learn that the large engine, 'Progress,' has to pass over a temporary piece of road where there is a curve of only 2½ chains radius, on a gradient of 1 in 30, which she does with the greatest ease and at the ordinary speed. The other day our men, curious to know what she could do, while ascending a gradient of 1 in 50 with fifteen trucks of 12 tons 10 cwt. each, gross, put down all the breaks of the trucks, but they failed to bring her to a stand. The small engine, 'Mountaineer,' is exactly the type of engine long wanted for branch lines with a heavy traffic. We tried her in the presence of a number of gentlemen with a load of 170 tons up a long gradient of 1 in 70, and were able to maintain a speed of from 16 to 18 miles per hour, with the steam blowing off all the time.

"I am, dear Sir, yours truly,
"Per pro JOHN DICKSON, W.R.Q.

"Neath and Brecon Railway, April 18th, 1866."

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## MR. FAIRLIE'S LOCOMOTIVE.

*From Engineering, Jan.* 12, 1866.

MR. FAIRLIE'S novel and very powerful engine, made for the Neath and Brecon Railway, and tried, the other day, at St. Helen's (where are situate the works of the constructors, Messrs. James Cross and Co.), is likely to instigate a change in heavy traffic engines everywhere. Not that the patentee has made any startling discovery, nor is there any magic in the results attained. He has, however, produced a thoroughly original design, while proceeding in a strict course of induction, from known facts, and from long experience with existing engines. Most goods and passenger engines are short of adhesion; that is to say, they will easily slip their driving wheels under full steam, especially if the rails are not quite dry and clean. And yet, in most cases, these engines have uncoupled leading or trailing wheels, and almost always a tender, contributing nothing to adhesion. Where this has been pointed out, it has commonly been said, "You can't well couple the tender to the engine in such manner as to obtain the additional adhesion due to the weight of both." But then one will say, "Cannot the tender be dispensed with, and fuel and water carried, as Braithwaite and Ericsson carried it thirty-six years ago, upon the engine itself?" The answer is always the same: "This would cause an excessive weight upon the permanent way, and it is to relieve the way that the tender is so generally employed." "But," it will be suggested by every reasoning mind, "cannot the increased weight of a tank engine be distributed upon an additional number of wheels, so as not to punish the way, wheel for wheel, more than at present?" And the answer is—and it is a just one—"Coupling more than three pairs of wheels together does not work well in the long run." They cannot be kept of exactly equal diameter, nor the coupling rods of the constant proper length. The Americans do, habitually, couple eight wheels of small diameter, and intended for slow speeds, and in the case of one very large "pushing" engine upon a bank on the Reading Railroad they have coupled twelve wheels, worked by a pair of 20-in. cylinders, with 26-in. stroke; but no one can approve of coupling so many wheels together for what we may call high speed goods traffic. There are engineers who have given much thought to this matter who believe that the resistances incurred by coupling are as the square of the number of wheels coupled, and there is much to justify their opinion. The attention to counter-weighting, to the wear of tyres, and to the adjustment of axle guards and coupling rod brasses, with eight, ten, or twelve coupled wheels, must be very considerable, perhaps we should say necessarily great, in order that all may work well together. Mr. Fairlie has said to himself, "I will have the adhesion of eight, or ten, or twelve wheels, carrying the whole weight of my tank engine; but I will work them in groups of four or six wheels each from separate pairs of cylinders." Now, the French have lately done this, and many four-cylinder passenger and goods engines, constructed by Gouin, of Paris, are regularly working on the Northern (French) line. But, upon the ordinary plan, four or six pairs of wheels, even if coupled in two separate groups, occupy much length upon the line; in other words, they cover a long "wheel base," and cause inconvenience in working around sharp curves. So Mr. Fairlie has gone further. He has, in his new eight-wheeled engine (of which we had the pleasure, lately, of watching the trials from the best point of observation, the foot plate), grouped four coupled wheels in each of two bogies, each carrying its own cylinders, rods, and valve gear. The bogies are connected together by a peculiar framing, which a drawing, soon to appear in our columns, will better explain, and the boiler (also of peculiar construction) rests equally upon both bogies. But, as the bogies with their cylinders move, by their pivoting motion, under the boiler, it is evident that the ordinary fixed connexion of the steam pipes and blast pipes is inapplicable. The steam pipe, which is of copper, is coiled once around within the smokebox, and in the direction of the circumference of the boiler, so that, as the bogie moves laterally, the pipe gives and takes, altering the diameter of its coil, much like the flattened tube of a Bourdon gauge when under varying pressures. The blast pipes are accommodated also with a kind of sliding joint, allowing freedom of motion, and still keeping the smokebox, as nearly as possible, air-tight. With these arrangements, the engine, upon a wheel base upwards of 22 ft. long, moves readily around curves of 170 ft., or rather more than 2½ chains' radius. The engine runs in either direction, without any necessity for turning upon turntables.

The boiler is not less peculiar. Its firebox is at the middle of its length, and two barrels and two sets of tubes, with their respective smokeboxes and chimneys, extend towards either end of the engine; the whole length of the boiler being, therefore, not far short of 30 ft. The stoker stands upon one side of the firebox, while the driver is upon the other. The bogies being connected by special framing, the boiler merely rests upon them, through proper supports, and is not strained longitudinally by any action of the respective pairs of pistons.

The engine tried on the 16th ult. at St. Helen's had eight wheels of 4½ ft. diameter each, grouped in two bogies. The cylinders of each bogie were 15 in. in diameter, with 22-in. stroke, being thus equal to a single pair of 21¼-in. cylinders, with the same stroke of pistons. With 100 lb. mean cylinder pressure, the mean tractive force should be 18,333 lb. The boiler had a firebox 6 ft. long upon the grate, 3 ft. 8 in. wide, and 4 ft. deep inside. The barrels were each 4 ft. in diameter, and each contained 194 tubes, or 388 collectively, each 1⅞ in. in external diameter, and 10 ft. long. The tube surface is set down as 1901 square feet, that of the firebox as 92 square feet, and the grate area 22 square feet. The tanks contain 1800 gallons of water, and 80 cubic feet of coal, or, say, two tons of the latter. The whole weight in working trim has not yet been ascertained upon a weigh-bridge, but it is estimated at from 42 tons to 48 tons, all of course available for adhesion.

On the occasion of a hasty trial, for which insufficient preparations had been made, the engine being at the time in an unfinished state, it drew 30 coal wagons, weighing upwards of 300 tons up an incline of 1 in 80, at a mean speed of more than 6 miles an hour. The builder, Mr. Cross, is confident that it will, when in good order, as readily take 500 tons up the same gradient. The boiler supplies an abundance of steam, and there is no want of adhesion with so great a total adhesion weight. Messrs. James Cross and Co. are constructing several smaller locomotives upon the same plan for the Venezuelan Central Railway, of which the patentee of the engine, Mr. Fairlie, is the chief engineer.

## A NOVEL LOCOMOTIVE.

*From the Engineer, December* 22, 1865.

On the 2nd of December, 1864, we illustrated and described in our pages a locomotive engine, invented and patented by Mr. Fairlie of Gracechurch-street. The general design of this engine was so remarkable, and differed so widely from anything hitherto adopted by English engineers, that while it was probable enough that the specification of the patent would attract some attention, it was also likely that nine-tenths of our readers would regard the entire scheme as that of an amateur, or at least of one little acquainted with modern railway practice. The inventor apparently rested content with securing his patent, and little or nothing has been heard of his engine during the last twelve months. Meanwhile, however, he has not been idle, and on Saturday last an engine very similar in its construction to that illustrated in the *Engineer* was tested on a section of the old Manchester and Liverpool line, close to St. Helen's, in the presence of a select party of engineers, men for the most part perfectly competent to pronounce a valuable opinion on the merits or demerits of the machine. The engine itself is so totally unlike any other locomotive in use in Great Britain, and the tests to which it was subjected were so eminently practical, that the entire experiment deserves due consideration at our hands. Indeed, since Mr. Fell's locomotive was tried at Whalley-bridge, on the Cromford and High-peak Railway, in 1864, nothing of more general interest has taken place in the world of locomotive engineering. In describing trials of novel machinery it is often difficult to avoid, on the one hand, overrating its performance, or, on the other, too greatly depreciating its value. And this difficulty is sensibly increased by the conditions under which the investigation is sometimes conducted. The impartial observer finds himself surrounded by individuals who either coincide in all the views of the inventor, and who regard the invention from his point of view, or by those who being thoroughly prejudiced against innovations on existing practice do not hesitate to pronounce the most positive opinions on insufficient data. There is no actual dishonesty in all this; but it renders the truth very difficult of access. The trial under consideration formed a very fair exception to this rule, and a fortunate coincidence enabled us to accurately compare the performance of Mr. Fairlie's engine with that of a heavy six-coupled goods engine over the same road. Thus, instead of being called upon to express an opinion which would just possess the value of an opinion and nothing more, we can discharge our duties by simply placing a general description of the engine before our readers, and the data connected with its performance.

We have frequently pointed out that the use of engines with a single pair of driving wheels is a mistake; because adhesion is for the greater part of the year deficient in our climate; because there are no insuperable, or even considerable, objections to the use of two pairs of driving wheels; and because, by the use of coupled drivers the tractive powers of a locomotive may be practically nearly doubled. It has also been shown that the tender represents a great unpaying load. It is of course a matter of necessity that coal and water should be carried in quantities sufficient for a considerable run; and did the matter end here, we should submit to the consequent loss of effect as a necessary evil. It happens, however, that this otherwise unpaying load may be made to subserve a good purpose under proper arrangements. In other words, it may be utilised in increasing adhesion. In order to carry out this object it is requisite either to carry the water and coal on the engine frame—as in tank engines—or else to render the wheels of the tender drivers, either by providing a pair of cylinders to put them in motion, as done by Verpilleur in France, and by Sturrock in England, or by coupling them with the engine wheels, as proposed by Engerth and others. On the whole, the tank engine represents the best system of utilising the load of fuel and water; but the ordinary tank engine is unsuitable for long runs, because under normal conditions it is impossible to find sufficient room on the framing for 1500 or 2000 gallons of water and a couple of tons of coal. This obstacle cannot be overcome by increasing the length of the machine without rendering the wheel base too long to pass round curves freely; and thus at the present moment in Great Britain the use of the tank engine has been confined within very circumscribed limits. We have reason to believe that there is not an engineer in the kingdom who does not recognise the full force of every argument which can be adduced in favour of the plan of carrying fuel and water on driving wheels, at least as far as regards heavy goods engines of which we speak more particularly just now. But the difficulties in the way are also recognised—by none, we will add, more fully than by ourselves.

Mr. Fairlie's engine embodies an attempt to reconcile the conflicting conditions to which we have just alluded. Whether this attempt has or has not been so far successful, we shall endeavour to place our readers in a position to judge for themselves. The engine already built has been constructed by Messrs. Cross and Co., of St. Helen's, for the Neath and Brecon Railway—a crooked, hilly line—where it will be employed almost exclusively in working mineral traffic. The firebox occupies the centre of the length of the engine. It is very similar to those habitually used, consisting of an inner and outer shell, with a water space between, and a grate at the bottom 6 ft. 6 in. long by 3 ft. 10 in. wide, giving an area of nearly 25 square feet. From each end of the firebox proceeds a cylindrical shell, 4 ft. diameter, containing 191 brass tubes 2 in. diameter outside and 9 ft. 6 in. long. The original patent includes a scheme for carrying return flues through the steam space to a central chimney placed above the firebox. This part of the design has been wisely omitted in the present engine to avoid complication, and therefore the tubes terminate in an ordinary smokebox at each end of the boiler, which has thus two funnels, and very much resembles two ordinary locomotive boilers placed back to back. The total heating surface amounts to rather more than 2000 square feet. At each side of the firebox a footplate is provided; on one the driver stands, on the other the fireman. The coal and water are carried in bunkers and tanks, extending from the ends of the firebox to those of the smokeboxes. The aggregate capacity of the tanks is over 2000 gallons, while the bunkers hold about 2·25 tons of coal. The boiler is supported at each end on a large bogie of somewhat peculiar construction. It is composed of a rectangular frame of iron, braced diagonally by deep plates terminating at the centre, where they are bolted to a heavy casting bored out to receive a bogie pin, nearly 8 in. in diameter, cast in one with a heavy saddle piece bolted to the bottom of the boiler. The bogie pins do not carry the entire weight of the engine, which, on the contrary, is principally supported on strong wrought-iron brackets bolted to the end plates of the bogie frames. Guard plates are also provided on the firebox to take the thrust of the trailing wheels, to prevent the bogies from crossing the track, and to reduce oscillation.

Each bogie is provided with four coupled wheels, 4 ft. 6 in. in diameter and 5 ft. from centre to centre, and two outside cylinders, 15 in. diameter and 22 in. stroke, fixed to the outer ends of the frames. On the axles are fitted friction wheels, to which the break blocks are applied by chain gearing worked from the fireman's footplate. The entire weight of the engine, with coal and water, amounting to about 42 tons, is thus supported on eight wheels. The load, therefore, averages but 5 tons per wheel, not too much for even a 50 lb. rail, and in this respect the machine contrasts very favourably with heavy tank engines of the ordinary type. Thus the Metropolitan narrow-gauge engines carry not less than 30 tons on four drivers, or 7½ tons per wheel; and this load, excessive as it is, is surpassed, we believe, on the London, Chatham, and Dover line. It will thus be seen that each bogie constitutes a distinct *engine;* and should any part of its machinery give way, the entire truck can be removed and replaced by another of the same dimensions in a very short space of time. The resistance due to coupling has been estimated as increasing in the ratio of the square of the number of wheels coupled; that is to say, if the resistance proper to a single pair of drivers be reckoned at so much, that of four coupled wheels will be four times greater, six coupled wheels sixteen as much, and so on. We are disposed to believe that this estimate is excessive; nevertheless it is certain that a considerable loss of useful effect is entailed by coupling more than four wheels. As it is, the locomotive under consideration apparently possesses the advantages of an eight-coupled engine without its disadvantages, against which fact must be set off the frictional resistance due to a second pair of cylinders and their gearing, which is probably not very serious if we consider the power exerted. As to the resistance due to curves, the engine is in precisely the same condition as two four-wheeled locomotives; and as it is always possible to make two points touch the arc of a circle, it follows that very little strain is thrown on the rails or the flanges as compared with an ordinary six-coupled locomotive. As it is, the engine passes round curves of less than three chains radius with perfect ease, the bogies swivelling each way from the centre about 3 in.; while the firebox, and, practically speaking, the centre of gravity, advance towards the centre of the curve by rather more than the like distance; a matter of some moment when sharp curves are to be traversed at comparatively high speeds. It will be seen that the design of the engine resembles in certain points that proposed and adopted by Meyer; but it must also be borne in mind that there are essential points of difference, particularly in the construction of the boiler, which suffice to distinguish Mr. Fairlie's engine from any other, either English or Continental. The method by which steam is brought to the cylinders constitutes one of the most elegant features in the entire design. In order to provide for the independent motion of the bogies it is obvious that the steam pipes must be rendered sufficiently flexible to follow the steam chests right and left, or that a system of movable joints must be introduced at some part of their length outside the steam space of the boiler. Mr. Fairlie has wisely adopted the former system. The steam pipes are made of hard copper, and they coil once round within the smokebox; the radius of curvature being so proportioned that free access to the flue tubes is permitted. The tubes pass out through slotted apertures in the bottom plates of the smokeboxes, and are rigidly connected to the steam chests by ordinary flanged joints. Thus, when the bogies swivel, the pipes coil or uncoil slightly within the smokeboxes. The system answers perfectly so far, and, judging from the results obtained from the somewhat similar arrangement employed by Mr. Sturrock in connexion with his steam tenders, there is no reason to fear that it will ever give trouble.

About mid-day on Saturday the engine left the erecting shops of Messrs. Cross and Co. for the first time. A few runs of a couple of hundred yards or so quickly proved that the machine was in the worst possible condition to undertake a trial trip. To say that the engine was unpainted is nothing; men had been at work on her night and day during the week, and the boiler was, as new boilers always are, exceedingly greasy and foul inside, and therefore disposed to prime copiously on the least provocation. The link motion, hastily put in place, required all those little refinements of adjustment on which the proper distribution of the steam invariably depends. In point of fact, in all our experience we never met with valves so badly set. Under the conditions it could not be otherwise, and it is only fair to the builders to add that they were very unwilling to have the engine tested at all while so far incomplete. Worst of all, an alteration from the original design had been made a day or two previously in the method of working the regulator; and as a result of night-work, we presume, no allowance was made for the expansion of a coupling rod; and thus, one regulator opening before the other, one pair of cylinders received steam before the other pair, and as the engine could not be run light with either regulator fully open, all the work was done at this time by one pair of engines. The engine was first tested by driving her over a curve of 191 ft. radius, round which she passed without any perceptible increase in the resistance. There was no grinding of the flanges, and the bogies swivelled exceedingly well. She then ran down the old Manchester and Liverpool line for a distance of about five miles, to the Sankey Canal, where she was coupled on to a train of thirty loaded wagons and a break van, representing a gross load of 300 tons. There are no grounds for questioning the accuracy of this estimate, as many thousands of such wagons pass through the hands of the officials during the year; and their own weight and that of the loads which they carry are accurately known. The train, too, was not specially made up for the trial. It was selected at haphazard from several waiting to be sent to their destination. With this load the engine started—steam being then taken by both bogies—with the utmost ease on an incline of 1 in 77; the boiler pressure being 100 lb. to the inch. The run to St. Helen's was accomplished, over a very hilly road, at the average speed of about fourteen miles per hour; a velocity of rather more than twenty miles per hour being maintained for part of the time. At St. Helen's the true test began, the line rising there on a long gradient commencing at 1 in 91, and increasing to 1 in 81·5, according to the sections. From the foul condition of the boiler it was found rather difficult to keep steam—a fact which may be further accounted for by the want of experience on the part of the stoker; the novelty of the method of firing from the side of the firebox; and the crowd of workmen who, availing themselves of the Saturday afternoon, swarmed all over the engine, scarcely leaving the stoker room to discharge his duties. Besides this, by a strange mistake the steam gauge is placed at the driver's side, as well as the safety-valve balances, and thus the fireman is left without anything to guide him but the condition of the furnace. As it was, when the train had reached within sixty yards of the summit of the bank, the pressure fell to 75 lb., and the engine came to a stand. In a few minutes the pressure ran up 5 lb. or 6 lb., and the incline was then easily surmounted with very slight assistance at the moment of starting from a pilot engine behind. The train was then shunted on to a siding, and the engine returned to the erecting shop.

The conditions under which experiments of this kind are conducted vary so much, that without some standard of comparison it is very difficult to estimate their results at their true value. Thus, as the wagons were not specially weighed for the occasion, nor the levels taken, it is quite possible that the load and the resistances may have been either a little greater or a little less than we have stated, and so far the trial was in a sense unsatisfactory. But by a fortunate coincidence we are enabled to supplement the foregoing particulars with those of the performance of another engine, engaged in the ordinary discharge of its duties on the very same piece of line, a couple of hours before Mr. Fairlie's engine was tested; and as the merits of any engine can only be comparative, we are thus able to form an accurate estimate of the real value of the performance we have just considered.

About eleven o'clock on Saturday morning a London and North-Western goods engine, of the "Atlas" class, attempted to ascend the St. Helen's bank with a train of thirty-five wagons, similar in every respect to those we have already spoken of. The engine crawled up the incline until it arrived at precisely the place where the new engine stopped subsequently. Beyond this point she could not proceed, and there the driver left his train and went for assistance. This engine has 18 in. cylinders, 24 in. stroke, and six coupled wheels 5 ft. in diameter. While on the bank steam blew profusely from the safety valves under a pressure of over 120 lb. to the inch—the load on the valves. No sand was used, and there was not the slightest tendency to slip. The weight of the engine is 26 tons 5 cwt. full; that of the tender 15 tons; or together, 41 tons 5 cwt. As the speed was excessively slow, the effective pressure with the cylinder cannot have been less than 110 lb. throughout the stroke. The tractive force of the machine calculated by Pambour's formula $T=\frac{D^2\ P.\ L}{W}$ was thus 14,256 lb., and the co-efficient of adhesion must have been at least ·244, and was more probably ·3; a very high result indeed to obtain with wheels carrying but 4·4 tons each on the average. The total weight moved amounted to, say 390 tons, or 873,600 lb. The resistance of gravity proper to this load on an incline of 1 in 81·5 amounted to 10,711 lb., and the difference between this and the actual tractive power exerted by the engine represents the friction of the wagons and the engine. This, however, would give a resistance as great as 9·1 lb. per ton, which is so high that we are disposed to believe that the incline at the steepest is more nearly 1 in 75 than 1 in 81·5, or else that the wagons weigh more than 10 tons. As it happens, the question is for our present purpose comparatively unimportant. The prominent fact is, that an engine weighing, with fuel and water, 42 tons, fresh from the erecting shop, and wasting at least 15 per cent. of its power as a result of the defective setting of the valves, hauled a train representing the maximum load of a goods engine of the ordinary type, in perfect order, and weighing with its tender 41·25 tons, with a pressure less by at least 30 lb. per inch. The tractive force which Mr. Fairlie's engine should be able to exert with 120 lb. steam in the boiler is easily shown by calculation to amount to 20,100 lb., and we have therefore no reason to doubt that she will prove herself perfectly competent to haul fifty wagons up a gradient of 1 in 81 as soon as her valves have been put in proper adjustment, and the friction proper to new machinery has disappeared. It will be seen that she possesses one-half more weight available for adhesion than the six-coupled engine, even with her tanks only half full, and is therefore apparently able to work up all the power her engines can develop, in fine weather without sand; while as regards facility of passing round curves there is hardly a comparison between the flexible double bogie system and the rigid frame carried on six-coupled wheels. In the matter of repairs of permanent way and working expenses—which, after all, are the most important questions at issue—it would be affectation to say that we doubted for a moment to which side the advantage would incline.

The principles on which Mr. Fairlie has gone to work are correct, and he does not lack skill as a designer; nevertheless much remains to be done ere his engines arrive at that degree of perfection which they are capable of attaining. There are several objectionable features about the engine already built, which are partly, if not wholly, inseparable from the first-born children of inventors' brains. Thus the stoker and the driver are effectually separated by the unnecessary height of the existing firebox, which rises far above the tops of the barrels. It would have been better, we think, to have obtained increased heating surface by adding to the length of the machine, rather than by employing a boiler of so great a diameter as 4 ft. Under somewhat different arrangements the footplates, excessively inconvenient just now, might be greatly improved. For the rest, it is not to be disputed that the engine is not handsome in our eyes—nor, indeed, in the eyes of any one familiar with the ordinary English types of locomotive. It is possible that the feeling would soon wear off under the all-persuading influence of custom, and in any case the point possesses no real importance. A steady system of gradual improvement has been the distinguishing feature of the policy of the English locomotive engineer for some years past, and it is not to be denied that it has upon the whole worked very well; the march of improvement is, nevertheless, sometimes rather too tardy, and we certainly have no reason to find fault with Mr. Fairlie because he has sprung away from his compeers. On the contrary, we wish him, and all those disposed to follow his example, every possible success.

# CORRESPONDENCE ON THE FAIRLIE ENGINE.

In addition to the articles contained in the foregoing pages, it has been deemed desirable to include in this pamphlet the following series of letters which appeared in *Engineering* during the close of 1866 and the beginning of 1867. The writers taking part in this correspondence were nearly all men of established standing in the railway world, and altogether the letters are of such a class that it is felt that they are certain to be read with interest by all connected with the practical working of railways.

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*To the Editor of Engineering.*

Sir,—I have read with much interest the able articles on locomotive engines that appeared in your journal on November 9th and 16th inst., headed "Four-cylinder Locomotives," and "Locomotive Engines," graphically pointing to the direction in which we are rapidly progressing towards the adoption of large and powerful locomotives to accommodate the vastly increasing traffic on our railways, and while I should remain satisfied with the flattering manner in which you have been pleased to mention my efforts in this direction, there are some essential points connected with the adoption and use of the locomotive so pertinent to the question, that I trust you will permit me to call your attention, and that of your readers, to them. In the consideration of this all-important subject, I think it but just and proper that we should consider the tender of a locomotive as a part of the locomotive itself, inasmuch as the one is as essential to the other as the cylinders to the driving wheels, consequently, when describing the character and performances of engines, we should treat them as of two classes—the engine and tender as one, and the tank engine as the other. Take, for example, the goods locomotives on the Great Western, North Western, Great Northern, and Midland Railways, as our best types, we shall find them what is usually termed six-wheeled coupled engines with tenders, the former weighing, in working order, about 36 tons, and the latter, with its complement of fuel and water, about 23 tons; consequently, in speaking of them, it is right to state the weight as 59 tons, 36 tons only of which is available for adhesion, the balance of 23 tons being a useless and very expensive load carried about with every move of the engine.

Let us now see what this 23 tons of load so uselessly carried about would produce on a line such as the North Western. The goods and minerals tonnage conveyed by this company for the half year ending June, 1866, according to their balance sheet, is 7,333,371 tons, or 46,700 net per working day for the half year, while the gross tonnage hauled, which, of course, includes the tare, the weight of the trucks being invariably put down at half the net, will amount to 70,050 tons.

Assuming each train to consist of thirty trucks, and each truck to average 10 tons gross, the number of tons per train will be 300, and the number of trains per day 234.

Suppose, then, instead of hauling these cumbersome, expensive, and useless tenders, trucks laden with goods are taken, each, as above, averaging 13 tons gross, it will give 2¼ additional trucks for every train; then multiply the number of trains per day, viz., 234, by the 2¼ trucks per train, and we have 527, this being the increased number of trucks taken per day at less expense for haulage than the tenders, because the latter are much more costly in production and maintenance. According to the average number of trucks per train, these 527, in lieu of tenders, would reduce the number of trains by *seventeen and a half*, producing a direct saving to revenue of this number of trains per day, together with all their attendant expenses, while the results for profit would remain precisely the same.

If, however, there should be traffic sufficient to load these 527 trucks, a circumstance that every merchant and manufacturer in London knows too well must be the case by the constant delay in receiving their goods, now greater than ever, notwithstanding all the increased facilities, the extra tonnage carried per day, allowing, as before stated, ⅓rd for the tare (the actual additional merchandise carried), will be 3513 tons in the 527 trucks, and, with 313 working days for a year, we shall find the result, in saving the weight of the tenders alone, to produce the enormous amount of 1,099,569 tons for that time. Assuming that this tonnage is hauled a distance of 100 miles at 1d. per ton per mile (which I consider below the average), it will produce 458,153*l.*, and, allowing for the necessary expenses of handling this tonnage, say, 30 per cent. of the tonnage rate per mile (the cost of haulage being already paid), there will still be left a net surplus revenue of considerably over a quarter of a million of money that would be available to go direct into the shareholders' pockets.

This is a startling fact, and should cause railway shareholders to open their eyes to the question, *why don't our railways pay?* How is it that fifteen years ago we received larger dividends than we receive now, notwithstanding that the traffic has during that time more than doubled itself? And this question becomes much more pertinent when it is known to every schoolboy that the cost of working any establishment is reduced in proportion to the quantity of work done. Ask a railway manager his rate of freight for 20 tons, and he will give a certain rate per ton; if you say 200 tons, the rate will be so much less, and properly so: but in connexion with shareholders' dividends the most common of all rules is reversed, for the more the traffic, the less the dividend. I need only instance the Brighton Railway, with the best paying traffic of any line in the world, and with more than they actually can accommodate; yet what is the result? The shares are actually at less value now than they ever were before. The same calculation will apply to this line, showing still greater advantages from applying the weight of the tender to that of carriages loaded with passengers, instead of trucks loaded with merchandise. Take only two carriages, weighing about 12 tons, and an average of fifteen passengers per carriage (the Brighton Railway being principally a passenger line, and I am informed the through traffic averages twenty passengers per carriage), weighing, say 3 tons, or only 15 tons gross, will give thirty passengers additional carried 1,000,000 miles per annum, being a very small portion of the mileage actually run; this is shown in their balance-sheet for the half year ending June, 1866, as 2,167,122 miles, or at the rate of 4,334,244 miles per annum, leaving the balance of the 1,000,000 miles taken for merchandise and unremunerative mileage, will produce, at the rate of three halfpence per passenger per mile, the sum of 187,500*l.* net profit per annum in favour of the shareholders, the cost per train mile for haulage being the same without this increased revenue as with it.

The reply to these extraordinary facts will no doubt be, we must have fuel and water to supply the engines, which we cannot carry on the engines themselves without incurring a corresponding increase of wear, tear, and maintenance, and in the cost thereof, by overloading, the engine wheels, and increasing considerably the danger of running at the speeds we are obliged to do with our express trains. The answer to this is a very simple one. Make your locomotives carry their own supplies, as well as do their own work; and I am prepared to prove this can be done without any increase in the cost of wear, tear, and maintenance—on the contrary, at a very considerable reduction in the present cost; but as to do this now would, I fear trespass too much on your valuable space, with your permission I shall be glad to continue this letter in your next edition.

I remain, your obedient Servant,

ROBERT F. FAIRLIE.

56, Gracechurch-street, London,
November 22, 1866.

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*To the Editor of Engineering.*

SIR,—I generally devote more time on Saturday evenings than I am able to do during the other portion of the week to the perusal of your ably conducted and important journal, and in connexion with yourself and your correspondent, Mr. Fairlie, I have taken great interest in the subject of light and heavy locomotive engines. Indeed, before the publication of Mr. Fairlie's letter in your last impression, I had thought of troubling you with some remarks on this head. I think Mr. Fairlie deserves all just praise and encouragement for his bold attempt to improve the working of railways in an economical point of view, and it is only after much careful consideration that I venture to differ from his views as to the relative advantages to be gained by the employment of large and powerful tank engines, such as he advocates. Believing, however, that much of Mr. Fairlie's argument is based upon erroneous figures, or, I may say, upon a wrong conception of facts, I have to offer the following remarks, which may not be without interest to those who are practically concerned in railway-working.

Mr. Fairlie selects four large companies, whose six-wheeled coupled goods engines and tenders he refers to as weighing, in working order, the former about 36, and the latter about 23 tons. With regard to the engines, I believe it will be found that the average of these four companies is considerably less than 36 tons. However, to follow Mr. Fairlie in his selection of the London and North-Western Company, I may state that during the last seven and a half years they have been building goods engines of their present type, weighing only 27 tons, which I firmly believe to be quite sufficient for the purpose of adhesion, even with their fastest and heaviest trains. As to the tenders, I am inclined to think that Mr. Fairlie has overstated their weight also, a narrow-gauge tender, such as those to which he refers, weighing only about 18 or 19 tons, with fuel and water; and as the latter will weigh something like 7 tons, Mr. Fairlie's 23 tons of "surplus load" becomes reduced at once to 11 or 12 tons, from which a further reduction must be made upon the obvious consideration that the 7 tons of fuel and water must be carried somewhere upon or about the engine.

I fear your correspondent is equally mistaken in his ideas as regards the tonnage and the tare of trucks, my impression being that a much larger tare is to be put down than he has calculated upon. Whether this be so or not, I am quite clear that the average loading, say again of the London and North-Western trucks, is not more than one-half of what he assumes it to be. According to his statement, a gross load of 10 tons carries about 6½ tons net; but in actual practice only about one-half of that weight is carried upon an average, the reason being that trucks are seldom loaded up to their maximum capacity, while, as a rule, mineral trains are run empty in one direction.

The rate of 1d. per ton per mile, which Mr. Fairlie considers "is below the average," is, I think, manifestly incorrect. He assumes that the "number of tons per train will be 300," and he puts the tare at half the net weight carried. This, of course, gives 200 tons of net load per train, which, at 1d. per ton per mile, would produce 16s. 8d. per train-mile run! Now the average earnings of the London and North-Western goods and mineral trains are only 6s. 3½d. per train per mile, that being, as I believe, the highest rate earned by any of the larger companies with their goods engines. Mineral traffic is generally conveyed for long distances at about one halfpenny per ton per mile, and, as before stated, the mineral trains being loaded only in one direction, it follows that the actual rate received is only one farthing per ton per mile.

I cannot coincide in Mr. Fairlie's views as regards diminished dividends, or the cause to which his reasoning points for such a reduction. It is, perhaps, scarcely fair either to refer to "fifteen years ago," a period which embraces the Exhibition of 1851, a special and exceptional time of increased dividends; but if we take the last seven years and a half as our ground, we shall find that most of the large companies have increased their dividends, while, to refer again to the London and North-Western Company, the dividend has been improved to the extent of 1 per cent. at least, solely by the saving of the locomotive department. I think that company may congratulate itself upon the possession of a "Sun" as well as a "Moon," and I am sure all the officers of that concern must have worked well together, to bring up their dividend from 4¾ to 7 per cent. But let us compare this with the expenses of the locomotive department of the Great Northern Railway. Upon that line there have been adopted the four-cylinder or improved tender engines, having the tender wheels coupled (for the express purpose of obtaining additional adhesion with heavy mineral trains). The rate per ton per mile received for this traffic is $\frac{3}{8}$ of a penny, which, taken upon the double journey (the trains running empty in one direction), gives only $\frac{3}{16}$ of a penny, and, consequently, we find from the printed accounts for the two half years ending December, 1865, and June, 1866, the following results:

*Traffic Earnings per Train per Mile.*

| | | s. | d. |
|---|---|---|---|
| Goods and Passenger | Great Northern . . . | 4 | 7·79 |
| | London and North-Western . | 5 | 9·79 |

*Locomotive Expenditure per cent. upon Receipts.*

| | |
|---|---|
| Great Northern . . . . . . | 16·6 |
| London and North-Western . . . . | 11·5 |

*Locomotive Expenditure per train-mile Run.*

| | d. |
|---|---|
| Great Northern . . . . . . . | 9·69 |
| London and North-Western . . . . | 8·09 |

I have no personal interest whatever in the London and North-Western line; but I may be excused, perhaps, for again referring to the locomotive department of that company, more especially as Mr. Fairlie has selected the same company for his own purposes of illustration. I will take the period since the present locomotive superintendent took charge of the whole of the locomotive department, which was, I think, about the time to which reference has already been made, viz., seven and a half years ago. That gentleman found in his northern division a *light* class of goods engine, and in the southern division those of a much *heavier* class. He struck out a new type—in weight a medium as regarded the former engines—and the result was the adoption of the goods engine of 27 tons, to which I have before alluded, a plain and simple engine, with cylinders 17 in. × 24 in. I have already shown the result. Seven years ago, when the traffic receipts per train per mile were lower than at present, their locomotive expenses were about 10d. per mile. Now, as I have shown, they are only 8d.—a saving upon the mileage of the year ending June, 1866, equal to nearly 180,000*l.*, notwithstanding that between forty and fifty new engines were built out of revenue (a much larger number than in the former period referred to), and a large sum spent upon machinery and other improvements. From the same source they have added to their stock altogether 150 duplicate engines, beside those which have been replaced, and their chairman recently stated to the proprietors that so well has the rolling stock been maintained and improved, that it is now worth more than 1,000,000*l.* more than the original cost, a statement which, knowing something of the matter, I can entirely corroborate. I think it might be a fair test of the merits of Mr. Fairlie's heavy engines, or of those of the Vale of Neath and the Great Northern Metropolitan engines, to which you alluded in a recent number, were they put to work such a traffic as that of the London and North-Western or of the Midland Company, and their results compared with those to which I have drawn your attention. One of the London and North-Western 27 tons goods engines costs 1700*l.*, including tender, manufactured in their own works, while the Vale of Neath and Great Northern tank engines cost 3330*l.*, including, of course, the maker's profits.

This question seems to turn upon the most efficient and economical method of working fast express trains over long distances and with few stops. Each of the four companies mentioned by Mr. Fairlie has to compete strongly for some of their best traffic; they have to run their most important goods trains to and from London and other places by night; they have to carry heavy loads, say fifty wagons per train; they have to run as fast as they possibly can, and they have few stops. All this is in order to insure an early delivery of their traffic in the large towns. Now, as Mr. Fairlie suggests the question, "Why don't our railways pay?" may I say that in some measure—perhaps more than is generally allowed—the answer is to be found in the public demand for quick transit, in the increased capital required for railway working compared with former periods, in the low rates of freightage induced by the competitive system, and in the higher value of labour and materials forming so important an item in railway expenditure.

I am, Sir, yours obediently,

TENDER ENGINE.

**November 27th, 1866.**

*To the Editor of Engineering.*

SIR,—In continuation of the subject in my letter which you were good enough to publish in your last week's issue, I beg to add a few other facts, in my opinion equally startling. I shall endeavour to place them before your readers in as simple a form as I possibly can.

To get at the real position of the question (which I presumed would suggest itself to many of your readers), I stated "we must have fuel and water to supply the engines," &c. In the first place, it will be necessary to analyse more clearly the component parts of the 23 tons forming the tender.

These will be found to consist of about 8 tons of water, 2 tons of coal, and 13 tons of frames, wheels, springs, &c.; consequently the actual necessary material required for the support of the locomotive is only about 10 out of 23 tons. With the addition of about 30 cwt. of plates to form the tanks and fuel bunkers, this additional weight would be available for adhesion, making the engine to that extent more effective; but locomotive engineers invariably object, and very properly so, unless when driven to it by pressure of traffic, to load their 6-wheeled coupled engines with more than 12 tons per pair, while they do not demur to put on their passenger engines as much as 14 and 16 tons on a single pair of driving wheels. The addition, therefore, of the water and fuel to the 36-ton engine would not exceed that placed now on the single driving wheels of passenger engines.

(In passing, the term "passenger engine" is used by the profession to denote engines with one pair of driving wheels, all the others being merely carrying wheels or rollers.) The Chatham and Dover have even more, exceeding, I believe, 34 tons on two pairs of wheels. However, what this company may choose to do is no criterion whatever, as it is stated they are in consequence obliged to renew, although it has been lamentably proved that they cannot afford it, portions of their permanent way once in three months.

No doubt the use of steel rails and tyres, as explained by you in the articles referred to in my previous letter, has mainly permitted the adoption and use of these excessive weights on wheels, greatly increased as this is by every oscillation of the superstructure of the engine, and in my opinion, even where steel is used, has not given the most satisfactory results, rather the contrary, while the adhesion per ton of weight placed on the rails is considerably less than that of good hard iron. Supposing it to be arranged that not more than 5 or 5½ tons, which I consider ample for all purposes of traction, be placed on locomotive wheels, rails such as I have seen produced by the Low-moor Company, with a very hard bearing surface, would be infinitely preferable to the finest steel both for wear and adhesion. Without, however, adding the weight of the water and fuel to the six wheels of the coupled engine, another pair could be added, that is, eight wheels coupled.

But exception would be taken to the extension of the wheel base, it being considered already too long, and there will be also the additional friction due to coupling another pair of wheels. The latter I have found from experience to be increased as near as possible as the square of the number of parts coupled on a straight line, and on a curve this is very much increased in proportion to the radius of the curve.

Notwithstanding that these are objections very serious indeed, yet I have reason to believe that a comparison between them and that of overloading the wheels, will be found to result very much in favour of the former. It is impossible, as you state in your able article on this subject, to ascertain the comparative cost of maintenance of lines, &c., and locomotives, between light and heavily laden wheels, nor can this be done effectively until we shall have railways which shall be worked by engines with no more weight on their wheels than on the carriages and trucks they have to haul, and with a reduced resistance on curves to a minimum. As we cannot hope to see this for many years, though I have faith in its ultimate adoption, it is but fair that I should urge the use of my system, which is equally applicable to the point, whether it be that locomotive engineers will continue to put 16 tons load on a pair of wheels, or reduce it to the average load of ordinary truck wheels—about 3 tons.

For example, with regard to the coupled goods engine and tender weighing 59 tons with 36 tons adhesion, I will guarantee to produce an engine of *one and a half times the power*, weighing 2 tons less per pair of wheels, which, at the same time, shall give 50 tons on the rails for adhesion, while the friction in running round curves will be reduced to a minimum. If I load my wheels to 12 tons per pair, the same as that on the 59-ton engine before described, I can produce an engine of *double the power*, and place 72 tons on the rails for adhesion, with a much less frictional resistance on curves, and supposing I load my wheels with 16 tons on a pair—and there can be no reasonable grounds for objecting to that which is now the general practice, and the exigencies of the traffic should render it necessary, as on the engines of the Metropolitan, North London, Great Northern, Vale of Neath, and Chatham and Dover Railways—I can produce an engine of *three times the power*, with 96 tons on the rails for adhesion, and the friction on curves reduced to a minimum. I assert and, if permitted, will prove that I can double the capacity of every railway in the United Kingdom without asking the shareholders to spend a penny in duplicating their lines, or increasing the expenses of maintenance beyond that of fair wear and tear, as I shall describe before concluding this letter. Some may be incredulous of these statements, but I only ask the directors of these railways properly to investigate the matter *without prejudice*. If they won't do so, let the shareholders form themselves into a commission for this purpose, and I am convinced that, without any professional preparation, I will satisfy their common sense that what I state is correct.

Is it not an admitted fact that our railways have been continually altered at an enormous outlay to the shareholders? We began with rails at 60 lb. per yard, then got to 68 lb., then to 72 lb., then to 84 lb., and now to 84 lb. steel rails. May I ask, was this necessary because of the increase of the size of the trucks, or the number of tons placed in each, or the increase of the number of trucks in a train? If the latter is really the case, and no one for a moment will doubt it, it follows that the rails which carried the first truck would carry the second, the number taken bearing no reference to the question. Then why the increase in the rails? Because, and it is monstrous to think of it, our railways have had to be made to sustain the locomotives as they had to be increased in size and their wheels overloaded, to get the necessary power and adhesion to haul the additional number of trucks added, by the increase of the traffic, to each train. Therefore I am right in asserting that the enormous expenditure which has taken place from time to time on our railways has not been on account of the increase of traffic, but of the increased weights placed on the driving wheels of the engines. The same weight of rails that carried a truck, the gross load of which was 3 tons on each wheel, 15 years ago, would certainly carry the same truck now; hence, as regards the trucks themselves and the merchandise to be carried, the rails might have remained the same to this day, providing, of course, that they were found sufficient for this weight. The wear of the rails under these circumstances would be reduced to that minimum, wearing out according to the number of trucks that passed over them, in precisely the same manner as a stone stairs would be worn out by the number of persons passing up and down them.

Permit me, before closing, to call your attention to a slight error in setting up my letter of last week. In the fourth paragraph, beginning with "Suppose, then, instead of hauling these cumbersome, &c., &c.," the average gross weight of a truck is put down at 13; this should read "as 10 tons."

I trust you and your readers will excuse all the imperfections that have appeared in these communications, and the length of time and your valuable space I have occupied with them. There are many who are far better able to take up a subject of so vast importance to the community, and to treat it in a very different manner, than I could ever do. Nevertheless, I have done my best, earnestly hoping that some good may result therefrom.

I remain, Sir, your obedient Servant,

ROBERT F. FAIRLIE.

56, Gracechurch-street, London, E.C.,
29th November, 1866.

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*To the Editor of Engineering.*

SIR,—Mr. Fairlie's views on locomotives, and especially on his own system, having in the course of two letters, and notably in the very good engraving you published last week, been placed before the public in a very matured form, perhaps you will allow a few remarks thereon in the way of friendly criticism. Mr. Fairlie believes that locomotives, as now made, especially tender engines, can be replaced with much advantage by engines of his duplex class, and that the latter attain a marked superiority in the following respects, viz.:

1. Reduction of dead weight to a minimum.
2. Amount of adhesional weight available.
3. Maximum flexibility on curves.
4. Compactness and general economy of construction.

It must be very generally admitted that the Queensland engine (constructed under the difficulties of the 3 ft. 6 in. gauge) shows an amount of careful designing that does much credit to all concerned, and puts the system fairly on its trial. The defects I wish to point out are such as (in my humble judgment) arise from the system itself.

The engine may be described as a sort of combination of two six-wheel tank engines, with certain peculiarities arising from the double boiler and double bogie arrangement, and my purpose is to ask if it be superior or inferior to two simple tank engines specially designed to couple back to back, and with one convenient platform *between* the two fireboxes. The following would be the distinctive differences of the two plans.

As regards the two engines coupled together, with intermediate buffers, and platform common to both.

1. That two independent regular handles and reversing levers would be needed.

This objection does not appear to the writer to be very serious, for the following reasons:

That both these levers can, by good equilibrium construction, be made to work with great freedom, and separately would only take half the power of the double lever.

That these important parts would be much more accessible, and therefore readily handled on a platform *between* the two fireboxes, than on Mr. Fairlie's *side* platform.

That the swivelling arrangement involves universal joints; that these might get out of order, and, on the score of safety, the advantage would rest with independent levers, both for reversing and for putting on the brake.

Much depends upon the frequency of stoppages; but for any class of work to which either engine could be wisely applied, two men and a boy would be the number of hands required.

That the two combined tank engines, as proposed, would, singly, present nothing different from ordinary simple construction, and by the centre connexion would take the same curve as Mr. Fairlie's engine.

That in case of repair one only would be laid off work in lieu of two.

The following seem to the writer more or less serious defects in Mr. Fairlie's system.

As regards the boiler:

That firing from the side is less convenient than the ordinary plan.

That atmospheric air entering the firedoor would pass sideways to the tubes, and that the economy derivable from the deflector and brick arch would not be available.

That on an incline there would be considerable difference of level of water in boiler.

That its great length and method of support would render straining in the centre likely in case of collision.

As regards the frames and general construction:

That the centre bogie pipe and bearer involve extra cost and *dead weight*, and interfere with space that might be more usefully applied.

That the unavoidable absence of a good fixing between the smokebox, tube-plate, and frames, the complexity, danger of leakage, liability of fracture of joints, and necessary inaccessibility for repair, of the arrangement for taking steam round barrels through bogie casting, and the telescopic pipe, are each serious drawbacks in practical working.

That the radial connexion at each of bogie frames, having to work freely, transmit the pull, and take weight of firebox, is (however carefully designed) inferior to the plain frame continued along firebox sides to trailing buffer beam.

That all the parts are so interbound, that a comparatively minor collision would send everything out of truth, make the tanks leak, and disable the machine.

That the side footplate arrangement separates driver and stoker, and gives very contracted room for working the engine.

It will certainly result that, if these criticisms be correct, little or no advantage can accrue from the adoption of this system as compared with ordinary tank engines.

Mr. Fairlie's calculations in your number of November 23rd, as to the dead weight involved in goods engine tender, though answered by "Tender Engine" in your last, demand a passing remark. The analysis of the weights of a 23 ton tender is as follows:

| | | |
|---|---|---|
| Water . . . . . . . . | 7½ to 8 | tons. |
| Coal . . . . . . . . | 2 to 2½ | „ |
| Tender tank . . . . . . . | 3 | „ |
| Tender frame . . . . . . . | 3 | „ |
| Three pairs of wheels . . . . | 4 | „ |
| Springs, brake gear, buffer, tools, &c. . | 3 | „ |
| Total . . . . | 23 | tons. |

In transferring this weight of water and fuel to the engine, at least two pairs of additional wheels would be required, which, with their adjuncts, would be as heavy as the three pairs of tender wheels. The brake work would also be the same, and the only item left as a gain on the gross weight would be the tender frame, or at the outside 3 tons.

Mr. Fairlie under-estimates a tank of the above size; in speaking of "30 cwt. of plates," made of $\frac{1}{4}$ to $\frac{5}{16}$ in. plate, the weight is not less than 3 tons, and whether carried on engine or tender it remains the same. The excessive amount of adhesional weight Mr. Fairlie aims at gaining, while necessary for exceptional incline work, is not required for the goods traffic worked by the 36 ton engines, whose economy is questioned.

Even on the Peterboro' London section of the Great Northern the 45 wagon trains taken by Mr. Sturrock's steam-tender engines are found troublesome from their length, want of managability, and the frequent fracture of coupling chains. For mineral traffic, pick-up and goods traffic, trains of 30 to 35 wagons are found most convenient, and it remains to be proved that for this duty any class of tank engine can be made that for speed, carrying capacity as regards fuel and general utility, will supersede the universal tender goods engine.

Tank engines have their distinct uses, and for some classes of traffic are invaluable; but the idea that they can be advantageously applied in all cases is probably erroneous.

Mr. F.'s calculation about the Brighton line, and the declining value of its stock, is more easily answered by referring to other causes than those "costly encumbrances," the poor tenders. A company with 100 miles of line that pay handsomely, and 200 that pay miserably, and with a near prospect of the cream of its traffic being trapped by new competing schemes, may well decline in prosperity. The writer therefore thinks that while Mr. Fairlie deserves credit for his attempts to improve the locomotive engine, the "startling facts" he adduces in support of his system are such as have a tendency to defeat the object he has in view.

I am, Sir, your obedient servant,
BETA.

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*To the Editor of Engineering.*

SIR,—I have read with much interest the letter of your correspondent "Tender Engine," and without desiring to take up too much of your valuable space, I will endeavour to reply as briefly as the interest of the subject will admit. Had "Tender Engine" favoured us with his views on locomotive engines, as he intended doing, my reply thereto would have been much less difficult, it being well known that to criticise is easier than to rebut criticism, and this is much more so when the subject introduced is of a novel and unusual character; this is my position, and I trust that not only "Tender Engine," but your readers, will, if I again occupy too much of your columns, suffer me to do so very "tender"-ly. If "Tender Engine" would consider calmly and dispassionately for a little, he would find that, in the definition of the reason he assigns for differing with me, viz. "as to the relative advantages to be gained by the employment of large and powerful tank engines," he would comprehend the whole head and front of my offending. I feel, speak, and write against "powerful tank engines" as they are meant by him; while the term tank may be applied to my engine as well as to any other that carries its own supplies, yet there is as wide a difference between my principle and that of the tank engine as there is between the latter and the tender engine. I assume, of course, that "Tender Engine" is fully aware of this fact (notwithstanding that I have known important matters criticised when the critic appeared to be unacquainted with the broad principles of the subject of his criticism); if he is not, I beg of him to read my pamphlet on locomotive engines, a copy of which I shall be happy to forward to him on application. Let us now look at the "wrong conception of facts" of which I have been guilty. I selected the great companies, of course, and in giving the weight of their goods engines at 36 tons, it is within my knowledge that about fifteen years ago the goods engines on the Great Western were 32 to 34 tons, the North Western 32½ to 33 tons, and I presumed that, with the requirements of the traffic, these weights would have been increased, the other companies mentioned increasing theirs *pro rata*. I have seen goods engines in working trim weighed on the North-Western Railway many years ago, and the result gave 32½ tons; however the weight of the engine was not the subject of my complaint, it was and is the tenders; I will therefore credit Mr. "Tender Engine" with the supposition that the engines are less than 36 tons, even down to 27 tons if he so desires it (so much the worse for adhesion). With regard to the tenders, I maintain that the weight of the large narrow-gauge tenders is, as stated by me, about 23 tons. The tenders of the goods and passenger engines on the North-Western Railway (the *ne plus ultra* railway in the opinion of "Tender Engine") weigh 22½ to 23 tons in working order. There are over one hundred of these tenders running on this line that were made at Crewe, and each contains 2000 gallons of water; the total weight is made up as follows:

| | Tons. |
|---|---|
| Tender, empty | 10¾ |
| Fuel | 3 |
| Water | 9 |
| Total | 22¾ |

The North-Western Railway had, in the Exhibition of 1862, an engine and tender, the weight of the latter, according to D. K. Clark in his "Exhibited Machinery of 1862," is given as 25 tons. It would have been unnecessary, therefore, to say more on this point, were it not that Mr. "Tender Engine," has taken exception to my argument as based upon "erroneous figures," and "a wrong conception of facts," but he has entirely failed to show that this is so, while I, on the other hand, beg to ask him from what source he has obtained his quantity of "7 tons of fuel and water" as the total carried by his tenders. If we take the weight of fuel, say 2 tons, from this estimate, it leaves only 5 tons for water, equivalent to about 1100 gallons. I would, therefore, ask him to point out any of the four railway companies that are building tenders containing only 1100 gallons. Why, his Crewe favourite, notwithstanding his patent system of scooping up supplies of water into the tenders from troughs placed between the rails, rendering very heavy tenders in this case unnecessary, has built, and is now building, tenders which weigh, loaded with fuel and water, 20½ tons, viz.:

| | Tons. | Cwts. |
|---|---|---|
| Tender | 10 | 0 |
| Water | 7 | 0 |
| Fuel | 3 | 10 |

It is the exception now to build tenders with a water capacity of 1500 gallons, the rule being to give them 1800 to 2000 gallons. The argument adduced by your correspondent, that the 23 tons I give as the surplus load, becoming "reduced at once to 11 or 12 tons," is totally wrong, as fully explained in my second letter on this subject.

Is it because out of the 20 tons (taking "Tender Engine's" own figures) that "7 tons of fuel and water must be carried somewhere," I am not to take advantage of this weight and debit it against the power of the engine, when I distinctly state that this 7 tons, if placed where it ought to be, would add nearly one-fourth to its adhesion, and consequently to its power; but, leaving out the question whether the 7 tons would be an advantage or disadvantage if applied as I state, I have a perfect right to deduct the full weight of the tender from the gross tonnage hauled, whether it be as "Tender Engine" states it is, in tare, nett, or gross, 23 tons is 23 tons, either in trucks or merchandise, and in estimating as I did that the trucks took their full load, was just as right to estimate that they took only one-half, or a fourth, or nothing at all. I could not, nor would the principle admit it, assume that trucks were worked containing only a small portion of the load they were built for and intended to carry; were I to do so, I should never get to facts. I am fully sensible that there are considerable numbers of empty trucks annually passed up and down the North-Western, as well as other lines, to accommodate the traffic which is unequal at all stations, instance the coal traffic alluded to by "Tender Engine," also that there are many classes of goods conveyed, such as crates of hats, and other delicate light goods, too bulky to load a truck to anything like its carrying weight; and I presume traffic managers take care that if one ton of any class of goods will fill a truck that should carry six tons, to charge 6 times the rate for the ton carried, with a large additional per centage to this amount for risk and damage in handling. Compensation for damaged goods, every manager knows, is a very serious item indeed, and he, of course, if he conducts his business properly, like an insurance office averaging the risks, averages the amounts and classes of goods upon which compensation has to be paid, and charges accordingly. Bar and pig iron and minerals are conveyed at the lowest rates, because a truck can readily be loaded with its maximum weight, and the articles themselves not being perishable, there is no loss sustained by damage. Hence I assert, as before, that I have a perfect right to set down the loss as the full load of each truck and the weight of the truck itself, and debit the expenses against the traffic, or add the increased tonnage to the profits, it being clearly understood that, with the exception alone of handling the goods and cartage (a small percentage of the usual cost being sufficient to cover this item), these profits would be nett to the shareholders. The coal traffic is entirely a different question, and yields, as represented by "Tender Engine," about a farthing a ton per mile, the trucks being loaded one way only; but even this argument of "Tender Engine" completely breaks down as against me, because of the reasons already stated and the following: The nett merchandise and minerals tonnage hauled, as shown by the North-Western Company's report, for the half year ending June, is 7,333,371 tons; let it be assumed that 3,000,000 tons of this quantity represents the coal traffic, or 19,170 tons net per working day for the half year. In this class of traffic, it is a very rare exception that a single truck is found in a train with less than its maximum load; the load carried is about twice the weight of the truck, and is invariably set down as such, being about 7½ to 8 tons of coal and 4 tons the truck, say 11½ tons gross.

The total nett daily tonnage being 19,170 tons, the gross number of tons hauled will be 29,192 taking the average of 30 trucks to a train of 11½ tons per truck, will give 345 tons per train, and 84½ trains of coal per day. The tender representing the gross weight of two trucks would yield in its stead this number of additional trucks to a train, and having 84½ trains per day gives 169 trucks, representing 1267 tons nett additional per day. This number of trucks hauled in lieu of tenders would reduce the number of trains daily by nearly six, together with all their attendant expenses. If, on the other hand, the 1267 tons is available for profit, the result would be, taking 313 working days, as before, for a year, and 1267 tons per day, to yield 406,571 tons per annum, that are hauled, say, 200 miles, and at the rate of one farthing per ton per mile, will produce the large sum of 84,702*l.* nett profit on this traffic alone.

This, however, is only one-half the saving effected, as the same calculation applies to the return empty trucks, which is rated by "Tender Engine" at one farthing per ton per mile, and at this rate the tender representing 5½ empty trucks, the above amount would be nearly, if not quite, doubled, which amount would be entirely available for the benefit of the shareholders.

I think it will be admitted it has been sufficiently shown that I have a right to take the full weight of the tender and dispose of it in the manner I have done between merchandise and trucks.

Let us now turn our attention to the rate of one penny per ton per mile for freight, which "Tender Engine" considers "manifestly incorrect." The rates given to me at one of the company's forwarding offices this day are as follows, viz.:

For crates of hats to Manchester, 3*l* 10s. per ton, or about 4½d. per ton per mile.

For bale goods to Manchester, 2*l.* per ton, or about 2½d. per ton per mile.

For manufactured iron of sizes to go inside an ordinary truck, 1*l.* 13s. 4d. per ton, or about 2⅛d. per ton per mile.

Surely if these are the proper rates, which I have no doubt they are, I have not been "manifestly incorrect," in estimating the average rate at 1d. per ton per mile, and considering it "below the average."

But "Tender Engine" evidently looks at the matter from one point of view only, viz. at the gross receipts for merchandise and minerals and mileage run, which yield, as he states, 6s. 3½d. per train mile. Let us see how this affects the question. I believe I have not overstated the gross load of the goods train on the North-Western Line; no doubt had I done so, Mr. "Tender Engine" would have corrected me; but it does appear very strange indeed to me that only 6s. 3½d. should be the gross result per train of goods per mile run, particularly as full loads of mineral traffic are always taken. Assuming the average rate to be 1½d. instead of 1d. per ton per mile, and this would appear to be nearer the mark by the rates quoted, the result is that there are 50 tons of goods nett at this price per ton hauled in a train, the gross load of which is 300 tons. There appears to be something radically wrong in this state of things, hauling 5 tons of unremunerative load composed of partially and wholly empty trucks to 1 ton of merchandise carried, excepting, of course, the minerals; it is clear, therefore, there is much to be done by the "Sun" and the "Moon" and their satellites to remedy this squandering of moneys that should go to enrich our unfortunate shareholders. Notwithstanding this, to me, very extraordinary result, the saving that would be effected in dispensing with the tenders, as I have shown, is precisely the same whether in unremunerative load or merchandise. It is much to be regretted that "Tender Engine" cannot coincide in my views as regards "diminished dividends;" he must have been most fortunate in his railway speculations. His last dividends from the North-Western, where, I presume, he has a large interest, although put down by him at 7 per cent., is only actually 6 per cent. on the ordinary share capital, and 4, 4½, and 5 per cent. on the other portions, making up the total capital of the company, leaving a balance of 28,000*l.*, equal to about $\frac{1}{15}$ per cent. on the entire capital. There are too many of my acquaintances that are not so fortunate, and can *feel* the *want* of diminished dividends too keenly, and moreover who are alive to any move that is likely to increase the very little they do get.

The latter part of "Tender Engine's" letter is foreign to the intention or desire of any portion of my letter to which he replies; it is simply a very interesting comparison in the cost of the locomotive departments between the Great Northern and North-Western Railways. The only part to which I take exception is his comparison between the four-cylinder principle of Mr. Sturrock and that of mine, differing as they do from each other in every respect; neither did I seek in my letter for any eulogy on any person; however, he has done this, and I beg to assure "Tender Engine" that it is with infinite pleasure I endorse every sentence he has written upon that very able man in command of the traction department of the North-Western Railway. By-the-by, I had almost forgotten to remark upon a statement in "Tender Engine's" letter, to the effect that he "firmly believed" 27 tons "to be quite sufficient for the purpose of adhesion even with their fastest and heaviest trains." I should be glad to learn upon what principle this belief is founded. I am inclined to think "Tender Engine" has been connected all his lifetime with railways that are about level, say, for instance, the Great Western Railway, which, with the exception of Box Tunnel, may be considered nearly so.

Why is it, if 27 tons weight is sufficient, that the Metropolitan, North London, Chatham and Dover, Vale of Neath, and Great Northern Railways require so much more? In the latter two cases they have engines weighing 56 tons, the whole of which is available for adhesion, and built especially for this purpose. The Vale of Neath Company could not work some portions of their line without this weight, and the Northern Railway of France were compelled to construct engines weighing 59 tons, with ten wheels, all coupled to get the necessary adhesion for working a line the ascent of which is 20 ft. per mile (it is understood, of course, that these ten wheels are worked by four cylinders). If, then, "Tender Engine" is correct in his assertion, as he apparently considers himself to be, all those gentlemen who specified such engines must be fit subjects for Hanwell, and the sooner they take a single ticket by the Great Western Railway to that establishment the better.

I am, Sir,
Your obedient Servant,
Robert F. Fairlie.

56, Gracechurch-street, London, E.C.,
December 6, 1866.

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*To the Editor of Engineering.*

Sir,—It is not my wish to prolong the correspondence on this subject, or to enter upon a controversy with Mr. Fairlie. It is, I think, quite plain from his mode of handling my former remarks, that there would soon be an ample field for disputation, and I will, therefore, with your permission, simply draw attention, as briefly as possible, to one or two points upon which I must still consider your able correspondent is much mistaken. In the first place, I would observe that this subject is not quite of "so novel and unusual," a character as Mr. Fairlie would make it appear, in proof of which I need only refer him to your own article on "Locomotive Designs," which appeared in *Engineering* of 26th January last.

Secondly, it may be as well to correct him in the assumptions with regard to myself, which occur in several places in his letter. I am not of the speculative turn of mind which he seems to have taken for granted. I have never been a shareholder in the L. and N. W. Company; nor, as I stated in my first letter, have I the least personal connexion with that concern; while my experience of railway working has *not* been of the kind he imagines, but, on the contrary, has included some knowledge of perhaps the heaviest gradients in the kingdom.

Thirdly, Mr. Fairlie's reference to the Great Western, as being, with the exception of Box Tunnel, nearly level, must, I apprehend, be classed with some other of his "assumptions," it being a fact that, as it stands to-day, that line is perhaps the heaviest of the four large lines which he mentioned in his first letter, by which I mean that the average of its gradients will be found to be heavier than any of the other three lines, while on several of the branches belonging to the G. W. R. the gradients reach as much as 1 in 45, and in one case even 1 in 28. Mr. Fairlie must surely have blotted out of his remembrance the Brimscomb, Evershot, Wooton Bassett, and other inclines on that railway.

I will not trespass upon your space or upon the patience of your readers, by attempting to follow Mr. Fairlie in his elaborate mode of trying to prove my former statements to be incorrect, and so far as regards my own "acquaintance with the broad principles of the subject," I am quite content to leave those statements and their criticism to the impartial judgment of practical railway men; but I do object to his continued reference to engines and tenders built "fifteen" and "many" years ago, while we are discussing those of present construction, as also to the Great Western (broad gauge) goods engines being quoted in justification of his views. If the broad gauge is to be brought into the argument, what will become of his calculations of tare and load, I cannot pretend to say, but they would certainly require modification to a large extent.

Next, as regards the L. and N. W. Exhibition engine, with the tender of 25 tons, it is perhaps beyond the knowledge of Mr. Fairlie that they offered it for sale, simply on account of its weight. As for the Crewe tenders, of which Mr. Fairlie states over one hundred are running on the L. and N. W. weighing 23 tons, I have not the means of testing the accuracy of this statement, but I know that they are not building tenders of that weight *now*. I believe the average weight of narrow gauge goods tenders, such as are now being built by the principal large companies, may be fairly taken at about 20 tons. I find that in my last letter I inadvertently took the weight of water alone, instead of fuel and water; but even allowing that the loaded tender does weigh 23 tons, I think Mr. Fairlie's theory is most completely answered by the plain practical remarks of your correspondent "Beta." I do not deny that every line has its specialities, and that at some points it may be necessary to employ heavier engines than at others, but I certainly do not consider that this is the proper view to take of the subject now before us.

In his opening letter, Mr. Fairlie speaks of this subject as "pointing to the direction in which we are rapidly progressing towards the adoption of large and powerful locomotives to accommodate the vastly increasing traffic on our railways." He then gave as examples four of the large lines, and afterwards proceeded to illustrate his own views by a special reference to one of those lines—viz. the London and North-Western. I ventured to call attention to what I still consider great inaccuracies in his mode of doing so, not only as regards the weights of engines and tenders, but also as to his calculations upon the gross and tare of the tonnage, and the traffic receipts of that railway, but I did not attempt to say that tank engines are never useful or never required. I took the broad principle of the ordinary working of large, through, competitive traffic, and I maintained, as I do now, that an engine of 27 tons, with a tender of 19 or 20 tons, is convenient, efficient, and economical. The long dissertation with which Mr. Fairlie has favoured us as regards traffic arrangements, tonnage, and the rates charged by one company for "crates of hats" and other merchandise, is surely not to the point, when it is as plain as figures can make it that the *earnings* of the company which has the best receipts only average 6s. 3½d. per mile. It is of no use for Mr. Fairlie to "assume" that which it is already proved does not exist, and although it may "appear very strange indeed to him," I am afraid his astonishment will not alter the fact. If his reasoning points to anything which is directly opposed to actual ascertained results, it falls to the ground; and I am much inclined to think that if he "assumes," in like manner, with regard to the performances of his own engines, he will "awake some morning and find himself" deceived. His remark about the "squandering of moneys" by a body of gentlemen who have attained such results as I have, on a previous occasion, feebly endeavoured to describe, is, to my mind, as unjust as it is uncalled for. I would recommend Mr. Fairlie to peruse again that portion of your article on "The Steam Tender" which commences at the fifteenth line from the bottom of the middle column of page 46 in the first volume of *Engineering*.

Mr. Fairlie says he will be glad to learn upon what principle my belief is founded, that 27 tons is quite sufficient for the purpose of adhesion even with their fastest and heaviest trains. My answer is, upon the principle of being guided by the results of practical experience, which is the safest principle of all. He also asks, in his last paragraph, "Why is it, if 27 tons is sufficient, that the Metropolitan, North London, Chatham and Dover, Vale of Neath, and Great Northern Railways require "so much more?" Now, although I *did not* say that 27 tons was sufficient for the cases here referred to, but simply for working the ordinary goods traffic upon the four lines he selected, still I must be understood as taking a very strong exception to the opinion that much more is actually necessary. I say that if the L. and N. W. engine of 27 tons was converted into a tank engine, and the diameter of the wheels reduced, although the weight would not then exceed 34 tons, it would be equal to the work of any of the lines to which he has yet referred. Some of the very engines he mentions—viz. those of the Metropolitan and North London Companies, have only 30 tons available for adhesion, the remaining weight being placed upon or consisting of the bogie in front!

I have some knowledge of the Vale of Neath Railway, and I can assure Mr. Fairlie that their 56 tons engines *do not* generally work trains in the ordinary acceptation of that phrase. They have only two of them, and they are used principally for banking up an incline of 1 in 47. The company has only purchased them within the last two years, and to say that they "could not work some portions of their line without this weight" is just as reasonable as to say that the neighbouring line, the Neath and Brecon, could not be worked without Mr. Fairlie's engine, and he knows how much or how little it has done so far. Upon this point I could say more, but as Mr. Fairlie asks to be treated "Tender-ly," I will forbear.

I am, Sir, yours obediently,

TENDER ENGINE.

18th December, 1866.

*To the Editor of Engineering.*

SIR,—In the interesting discussion on locomotive engines, it appears "Tender Engine" considers 27 tons sufficient weight for adhesion in the six-wheel goods engines employed on the London and North-Western Railway. Mr. Fairlie evidently considers it is not sufficient; but neither of them gives the diameter of cylinders, length of stroke, or diameter of driving wheels, If we take five times the greatest amount of traction as the necessary weight for adhesion, and, for illustration, we take the average available pressure as 100 lb. throughout the entire stroke of the piston, we have simply to multiply the area of one cylinder by that pressure, and again by the length of stroke of all the pistons, and divide by the circumference of the driving wheels, the quotient represents that traction in pounds,* and five times that amount gives the required weight for adhesion.

In your paper of the 9th ultimo, you give some dimensions and weight of one of Mr. Fairlie's four-cylinder tank engines, as 18 in. cylinders, 24 in. stroke, and 4 ft. driving wheels. Applying the above rule to this engine, we have $\frac{254 \times 100 \times 16}{12{\cdot}5} = 32{,}512$ lb., and five times that force is equal to 72·5 tons, as the necessary amount of weight for adhesion; 72 tons is given as the estimated weight that the engine is expected to weigh. The North-Western Railway Company have some goods engines that have 18 in. cylinders, 24 in. stroke, and 5 ft. driving wheels, having a traction of 12,942 lb., and requiring for adhesion 28·8 tons. Others have 17 in. cylinders, with the same stroke and diameter of driving wheel, having a traction of 11,516 lb., requiring 26 tons for adhesion. Both of these classes have six wheels, coupled, and fenders.

On the Great Eastern Railway they use for their fast and important goods trains six-wheel engines, but only four wheels coupled. They have 17 in. cylinders, 24 in. stroke, and 6 ft. driving wheels, giving a traction of 9617 lb., requiring for adhesion 21·4 tons. Mr. Clark gives the weight on the four coupled wheels of one of these engines exhibited in 1862 as 20·75 tons. He also gives particulars of two passenger engines exhibited belonging to the London and North-Western Railway. They had both the same stroke, 24 in., and the same diameter of driving wheel, 7 ft. 6 in.; but one had 18 in. cylinder, and the other had only 16 in. The 18 in. represents a traction of 8646 lb., requiring for adhesion 19·3 tons, whereas she had only 14·3. The 16 in. represents a traction of 6808 lb., and for adhesion 15·1 tons; but by Mr. Clark's account she had only 11·5 tons. It has been mentioned in the discussion that the Great Northern Railway Company are having new engines, weighing 56 tons, carried upon eight wheels coupled. They have, I believe, a few of these engines intended for special use in taking heavy coal trains over the Metropolitan Railway. I have been given to understand their dimensions are 19·5 in. cylinders, 24 in. stroke, and 4 ft. driving wheels, giving a traction of 19,072 lb., requiring 42·5 tons for adhesion. From this it would appear that although they are tank engines weighing 56 tons they are not necessarily so for adhesion, but as more convenient for the short distance they have to run without stopping. This is, in my opinion, one of those cases where Mr. Fairlie's twelve-wheel four-cylinder engines would be more at home than in competition with the six-wheel tender engines running long distances with fast goods trains.

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* A rule much simpler of application is to multiply the square of the diameter of cylinder, in inches, by the mean pressure in pounds per square inch, and to multiply this product by the length of stroke of *one* piston, instead of "all the pistons," as Mr. Naylor observes. Then divide the final product by the diameter of the driving wheel, the stroke and the diameter of the driving wheel being both taken in feet, where convenient, or, otherwise, both in inches.—ED. E.

Mr. Fairlie deserves great credit for his enterprising spirit in departing from the beaten track; it is those who believe that there are improvements to be made, and attempt them, that open the way, if they do not accomplish all they wish. There are large tracts in mountainous districts where railways have to be made with steep gradients and sharp curves for the purpose of obtaining minerals and other produce, which have to be conveyed in large quantities over cheaply constructed lines and light rails. Those are the fields for Mr. Fairlie to cultivate, where he will be more at home than by competing for the entire farm of railways on the plains as well as amongst the hills.

A few words for the tender. It is patent to every one practically acquainted with the working of railways that goods and mineral trains are notoriously short of brake power, there are several ingenious contrivances of continuous brakes for passenger trains, but none as yet for goods trains; for although every wagon may have its individual brake, they are not of the slightest use in preventing an unexpected collision, from the fact that they cannot be got at in time to be of any service. Take a heavy coal train, for instance, with its two heavy brake vans drawn along, with both full wagons and empty wagons, for no other purpose than to assist in retarding or stopping the train; the tender comes into use in a place of a third brake van, which would be required if the tender was not there. It may be said, "but on the tank engine we have a brake;" so there might be on the six-wheel goods engine. It is not, however, the practice to fix a brake to these engines, but to have recourse to reversing the engine to give additional retarding power to meet any case of emergency; and if there is a brake on the engine, there is no reserve of power in reversing the engine, for if the brake absorbs all the adhesive power, there is no more to be gained.

Yours respectfully,
Wm. Naylor.

3, New Broad-street, E.C., December 18, 1866.

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*To the Editor of Engineering.*

Sir,—There are two or three points in your correspondent "Beta's" letter that have not been answered in my reply of the 6th inst. to "Tender Engine," requiring a few passing observations, for which I trust you will kindly find space in your columns of this week's publication.

In your very able article on "Light Railways," in your paper of the 7th inst., and the letter referred to, will be found a complete answer to the general subject of "Beta's" communication, and the remaining points are fully answered by "Beta" himself, as he will admit, after he has taken the trouble to reconsider his letter.

It is needless to trouble your readers with matters of mere detail —such as platforms, driving and reversing gear, stoking arrangements, &c.—or to attempt to show on paper that my engine is *not* the "combination" of difficulties described by "Beta," or that in these respects it is so inferior to the twin-tank engine as he strives to make out.

It will suffice to say that in practice (I always answer inquirers on these points, that the proof of the pudding, &c., &c.) no difficulty whatever has been experienced; on the contrary, my arrangement is much simpler than any "two combined tank engines of simple construction," stated by "Beta" to be the acme of perfection; whereas all the attempts that have been made to make the twin engines successful, including those of the late Mr. Robert Stephenson for the Ghaut incline, in India, have notoriously failed. The twin-engine arrangement is not so simple as "Beta" would have us believe; moreover, with regard to working those engines by "two men and a boy," I believe the number of men required was one of the chief objections to their adoption. To drive the two engines with the ordinary number of hands, it would be necessary that the drivers and firemen should take a series of lessons from Leotard, or other clever contortionist, from whom they would have to get a certificate to prove that they were capable of being in two places at once, Economy in repairs and easy access to them are amongst the advantages of my principle, whatever "Beta" may write to the contrary: here again my reply is that the proof of the pudding is in the eating. All experience to this time is in my favour, and I am confident will remain so. "Beta" must be the reverse of the tank engines—of "simple construction"—if he can show that two such engines coupled together can traverse the same curve that one of mine can. Let us carefully look at this point, one of the most important claimed by me; for instance, all the axles of the twin engines must either be placed under the cylindrical part of the boiler, or two under this part and one under the footplate behind the firebox; consequently, if the former plan be adopted, the distance from the centre of the trailing axle of each engine and the end of the footplate, where the coupling is effected, would be so great as virtually to prevent the engines traversing safely any curve under ¼ to ½ mile radius; and if the latter plan be adopted, the wheel base must always be considerably more than the length of the firebox in excess of my engine, and as the length of wheel base necessarily is the measure of the curve the engine can traverse, it follows that in neither case can the two coupled engines traverse the same curve that my engine can. "Beta's" assertion to the contrary falls before these simple facts. However, further to set at rest this question, "that my engine is the same in principle as the two engines coupled together, with a great many disadvantages," and to prevent your valuable space and my time being unnecessarily taken up in discussing a matter so clear to all practical minds, I adduce the following additional illustrations:

My 72 tons goods engine, with 6 tons on each wheel, measures 35 ft. in length between the smokebox tube-plates, viz., firebox shell, 12 ft.; and two boiler barrels, 11 ft. 6 in. each. Under each barrel are placed three pairs of wheels close together, in an independent bogie frame, on which half of the entire weight of the boiler and its accessories are carried, say 30 tons, distributed equally over it, *from its centre to each wheel.* This weight is *never varied,* continuing the same under all circumstances. The six-wheeled tank engine is the reverse of this, notwithstanding that the weight on each of its wheels when at rest is 6 tons, but when in motion a change takes place with every oscillation of the superstructure, placing at one moment 9 or 10 tons on one wheel and 3 tons on another, in exact proportion to the rise and fall of the engine on its springs.

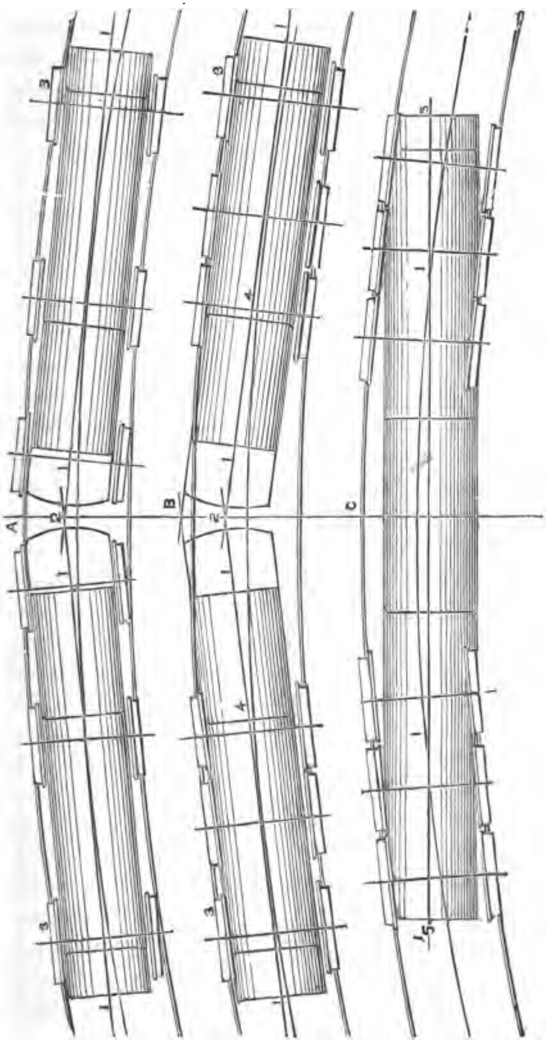
This will be better understood by explaining that in all ordinary cases (exceptional cases, such as the overloaded wheels of the Chatham and Dover engines, are much worse) a spring when loaded to 6 tons reduces its camber 1½ in., or graduating from 1 ton at the commencement for every ¼ of an inch to 1¼ tons on the last quarter. If then, as we know in practice, the engine frame moves up and down on the axles from ½ to ¾ of an inch, it is clear that the weight put on the spring by the oscillation of the engine forcing the frame down ¾ of an inch must be precisely the same load as that which would reduce the camber of the spring that distance beyond its normal position, showing that the additional weight thrown on each wheel at certain times by this calculation is from 9 to 10 tons, or more than half that which is necessary. In the Chatham and Dover engines, with 8 to 8½ tons load per wheel, the weight on some of them is frequently increased to 13 tons, producing the steam hammer blows that are so destructive to the rails, necessitating never-ending repairs and renewals, as the shareholders of this line know too well to their cost.

The following diagrams, drawn to ⅛ in. scale, will show the positions of the three descriptions of engine referred to.

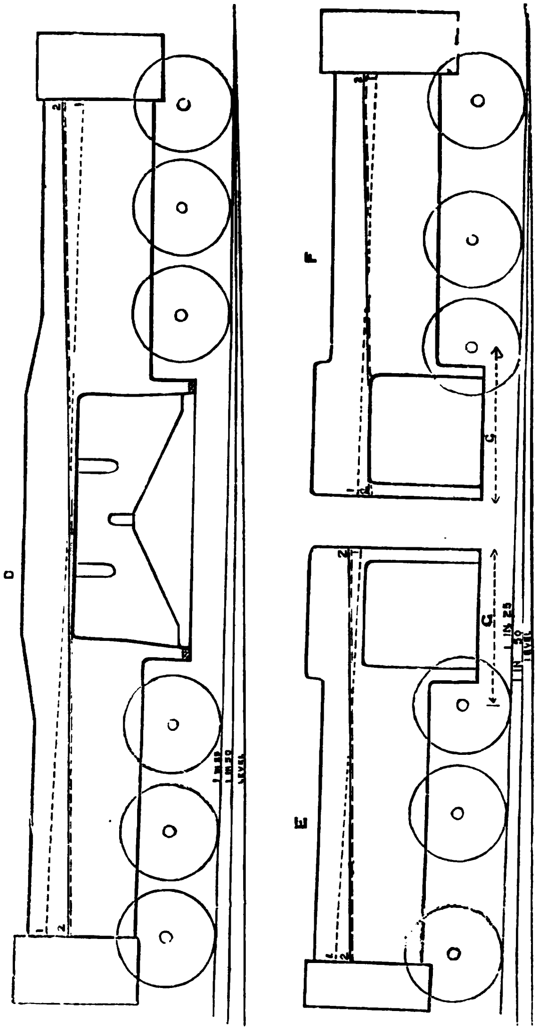
A is the twin engine, with the wheel base extending to the rear of the firebox, and measuring 15 ft. 9 in. extreme centres; B the twin engine, with wheel base under the barrel of the boiler, as usual in such cases, measuring 10 ft. 6 in. extreme centres; and C, Fairlie's patent engine, with wheel base 8 ft. 6 in. extreme centres.

No. 1 in each case is the centre line of boiler, and in A B represents the centre line of engine also; No. 2 in A B only, the distance outside the centre line of the curve that the connexion between the two engines must take, also showing the angle at which the engines working are opposed to each other, the effect on each being the full application of the other's power to straighten this angle, and consequent enormous strain and side friction on the outside end wheels, No. 3.

This angle is so great in the short wheel base twin engine B, combined with the enormous leverage given to the coupling from 2 to 4, that it would be impossible, to say nothing of the risk, to work these engines on curves at all.



The end wheels of A will be seen inside and outside the line altogether, and the centre of traction at either end outside the centre line of curve, thereby increasing immensely the friction of the vehicles following the engine against the outer line of rails, if they were not pulled off altogether, the latter, in nine cases out of ten, would, in my opinion, be the result. Too much attention cannot be given to



keeping the centre line of traction to the centre line of curve. This is one of the most important considerations in the locomotive.

No. 5 in C is the centre line of traction, and will be found to come the nearest of any other system yet discovered to the centre line of curve.

The next question of importance raised in "Beta's" letter is, "that on an incline there would be a considerable difference of level of water in boiler." This I admit freely; but, as he has put the question, it is clear he means that, because my boiler is a long one (35 ft.), the difference of level of water in it and that in the boilers of the two tank engines would be greatly in favour of the latter. Let us see how this works out. The firebox on my principle being in the centre of the boiler, whatever be the height of the water over its centre when on the level it would be precisely the same on any incline; thus, suppose there were 3 in. of water over a horizontal firebox, 10 ft. long, place the same on an incline of 1 in 20, and the water would just cover one end of it, while there would be 6 in. over the other end. The tubes at the smokebox end would be uncovered for some distance towards the firebox. This, however, is not very important, as the main point to be considered is the *keeping the firebox always covered with water.*

Now, place the two tank engines together on the same incline with the same level of water over the firebox, and in one case the tubes would be uncovered at the smokebox end, just as in my case, and in the other the firebox would be partially uncovered. Precisely at one-half the distance from the tubeplate to the back shellplate of firebox is the axis of the water in the tank engine, while the centre of the firebox is, in my engine, the axis. The following diagrams will explain this advantage more fully.

D represents my engine on an incline of 1 in 25, E, F, the twin engines on the same incline.

No. 1 in each case is the top line of the water in the boilers on the level.

No. 2 in each case, the top line of the water on the incline, which will be seen in D to cover the firebox at all points, while in F the firebox is uncovered for a distance of 2 ft. at the highest end.

The overhang, G, in the diagrams E and F, will give a pretty good notion of the form of steam hammer this engine would make to thump the substructure and rails to pieces.

"Beta" will, I am sure, readily admit the proof I give in favour of the long boiler as against the twin boilers.

The analysis of the tender-weights by "Beta" scarcely requires notice; it is sufficient to point out the absurdity of attaching two extra pairs of wheels to an engine in order to carry the 10 or 11 tons of water and fuel required. I am greatly obliged, however, for the statement, as it is an admission in favour of ten wheels out of the twelve required for my heavy goods engine; my statement of 30 cwt. plates to form the tank on an engine is quite correct. "Beta" forgets that the footplates of the engine would form the bottom plates of the tank, so that only side, end, and top plates would be required of the usual dimensions—viz. $\frac{3}{16}$ instead of $\frac{1}{4}$ and $\frac{5}{16}$.

It is quite a new idea that the length of our trains must be limited to thirty or thirty-five wagons; if this were so, there would be an end to all advancement, and we had better shut up at once. Why did we not think of this twenty to twenty-five years ago, before we impoverished our shareholders as we have done by rebuilding our railways at enormous outlays, doubling the weight and trebling the cost of the permanent way, and then designing Nasmyth's hammers in the form of locomotive engines, that should the most efficiently and quickly hammer all to pieces. Truly we are a great and wonderful people to build up monsters for the pleasure of battering them down again. Unquestionably, however, it is the true science to be able to *make* and *unmake*, totally irrespective of shareholders or their resources; however, shareholders are opening their eyes to this fact, and are buttoning their pockets in consequence. I know many excellent schemes for railways, for which all the necessary powers have been obtained from Parliament, and yet there has not been sufficient money subscribed by the public to pay the cost of the surveys. This is a lamentable fact, and one that requires the earnest and immediate attention of every engineer in this country. Shareholders will no longer allow us to build up monuments to our individual fame out of their pockets, such as I consider the Cannon-street Station to be. It would be much better for the country and its prosperity that money should be employed in constructing that which is actually required, and not unnecessary monsters. When we want monuments, we should go properly to the public for a voluntary subscription, and instead of paying fabulous sums for a site in the city of London, go to Egypt, where there is ample room for a lot more pyramids.

I remain, Sir,
R. F. FAIRLIE.

56, Gracechurch-street, 13th Dec., 1866.

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*To the Editor of Engineering.*

SIR,—I have been much interested in reading the correspondence on "Locomotive Engines," in your excellent paper, for the last few weeks, and which has been so ably conducted on both sides that I feel very loth to interrupt it, nor indeed do I desire it now, as much good must result from the discussion; but as "Tender Engine," at the end of his letter in your issue of last week, made some equivocal remarks on one of Fairlie's patent engines on this line, which might convey the impression that this engine has not been so successful as was anticipated, permit me, in common justice to Mr. Fairlie and the principle he advocates, to state that although hitherto the engine has not proved the success that he (Mr. Fairlie) and others could have wished, it is not from any inherent defects in the principle, as the following performances will show. When the engine first came to Neath, her usual load was very rarely less than 20 wagons loaded with metals, coal, sleepers, &c., besides empties, and on one occasion she pulled with the greatest ease 23 loaded and 15 empty wagons a distance of five miles on a gradient of 1 in 50, while from Neath to the Bulch, a distance of seventeen miles, she has frequently taken as many as 19 or 20 loaded wagons and 6 or 7 empties. For a still greater performance I must refer "Tender Engine" and other readers to a letter from Mr. Dickson, inserted at page 260, vol i., of ENGINEERING. Now when it is considered that the engine did this on a new and in some parts temporary road over a line with an ascending gradient for seventeen miles, the vertical rise in that distance being 1225 ft. with frequent gradients of 1 in 50, and with a constant succession of S curves, without a straight piece of road half a mile long, I think it will be admitted that these were very creditable performances, and that the engine is not the failure "Tender Engine" so tender-ly implies.

To contrast with this, on one occasion we borrowed a 6-wheeled coupled engine, cylinders 16½ in. in diameter, 24 in. stroke, wheels 5 ft. diameter, and started from Neath with 15 loaded wagons; but she stopped dead, with steam blowing off at 160 lb., before running three miles, probably owing to the power being mostly absorbed by the great friction in passing round the numerous curves. The train had to be divided; and I maintain that, if we are not to be limited to 10 or 12 wagons, it is by no means certain that the Neath and Brecon line can be successfully worked without Mr. Fairlie's engines. I need hardly allude to the easy and I might almost say graceful manner in which this engine takes the curves, even at the rate of sixty miles per hour, at which speed I have on several occasions run her, frequently accompanied by gentlemen connected with railways in this part, and all have expressed their opinions that no ordinary type of engine could be run with safety on this line at such a speed, and also their astonishment at her remarkable freedom from oscillation and perfect steadiness when running hard. I cannot here explain the reason this engine is temporarily laid up; suffice it that the engine was very hastily constructed, and the details very imperfectly carried out. In two or three weeks, however, I trust she will be in first-class order, and if "Tender Engine" or "Beta" will honour me with their company on the footplate, I think I shall be able to dispel some of their prejudices, and even make converts of them to a principle which I believe will turn out as complete a success as has ever been claimed or conceived by the inventor; and so confident are the managers of the line of this, that they have ordered *another* engine of similar construction, and this will, I hope, be in full work before many days with important results, which I will take care are tabulated.

I have no other object in writing this letter than to do justice to one who is striving, under many disadvantages, to improve locomotive engines by rendering them suitable for the present construction of railways, and I feel that while a rigorous investigation should be continued to prove whether Mr. Fairlie is right or wrong, that needless and frivolous objections should be kept out of his way, and that he should be allowed a fair field.

I remain, Sir,
Yours respectfully,
Wm. Lyster Holt,
Locomotive Superintendent.

Neath, December 24, 1866.

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*To the Editor of Engineering.*

Sir,—Your correspondent, "Tender Engine," evidently forgets that in his letter of the 30th of last month he said, "I think Mr. Fairlie deserves all just praise and encouragement." He must know, therefore, that encouragement does much to help in achieving that which is aimed at, and I am sorry that he should now so much disparage my invention. I maintain that my principle is "novel and unusual," and as yours is the only journal in which the engine referred to by him has been illustrated and explained, I appeal to you whether that engine did not make its appearance long after the principles I advocate were made public by me when I took out my patent in 1864, and I wish to state emphatically that it was not until after my return from a professional visit to South America, in May of this year, that I learnt anything approximating even to my principle, Your correspondent is one of the most gifted writers I have met with, for he has given us two exceedingly clever and interesting letters of some length without once dealing with the real question at issue.

I showed the cost of running tenders with locomotives, and the saving which would be effected by their being dispensed with. He called my statement in question because he said I took the weight of the tender at 23 tons, meaning heavy goods engine tenders, instead of 19 or 20 tons. I again assert that on the narrow gauge line referred to there are over 100 tenders weighing 22¾ tons when loaded. What I cannot understand is that, notwithstanding his apparent intimacy with so very many of the circumstances of the North-Western Railway, he pleads entire ignorance of this material fact, so easily ascertained, and which it was his duty to make himself acquainted with before calling my statement in question, and yet he is wonderfully well informed of the fact, of which it is quite true I was unaware, that the 25 ton tender exhibited by that company was offered for sale because, as he gravely informs us, it was too heavy.

With reference to the Great Western Railway, I believe that within the last month or so this company has taken over some branches having the heavy gradients described by "Tender Engine," it may be that elsewhere on some short branch there are the like gradients; but he knows that substantially the main line is what I have described it. If your correspondent has any connexion with that company, as I suspect he has, he may easily ascertain whether a 27 ton engine is sufficient on all occasions to work a gradient of 1 in 45 for any length, to say nothing of 1 in 28. He, however, admits that *all* lines have specialities requiring *heavier* engines at one point than at another. For what purpose, I should like "Tender Engine" to inform me, are the engines under such circumstance to be made *heavier?* But to put an end to his scepticism, I refer him to your article of Saturday last on "French Locomotives," which, I submit, is conclusive on this point.

The locomotive engine has for some time past been the subject of much attention, arising from the necessity for greater traction and adhesive power. In this will be found the secret of diminished dividends and the discredit which now so generally attaches to railway investments, and hence my appearance as an inventor and correspondent, for this I am taken to task by "Tender Engine" and "Beta;" but with deference to them I venture to predict that the reform of our railway system will ere long become one of the great questions of the day. If they are satisfied with the state of things as they now exist, I am not, nor will the public be. "Tender Engine" clearly considers the London and North-Western to be perfection itself. He, like "Beta," thinks we should be content with a maximum train of 35 wagons, to go beyond which they deprecate as if it were useless, inconvenient, and costly. If this doctrine is to prevail, and the trade and commerce of the kingdom is to continue to increase as it has done, railway shareholders must make up their minds to finding more money for additional lines, as has been done by the London and North-Western Company to or near Rugby, new branches, and, in short, everything but *improved* locomotives adapted to the requirements of the times. Will "Tender Engine" allow me to suggest to him in all kindness that "there are more things in heaven and earth than are dreamt of in his philosophy?" and that if he does not adapt himself to the changes which are imperative, they will pass him by and leave him far behind. He charges me with all sorts of inaccuracies and assumptions without disproving them, contenting himself with the convenient proverbial argument with ladies, "because it is."

I don't grudge him his joke about "crates of hats," being as fond of pleasantry as any one; but when I referred to them and other descriptions of merchandise, it was for the purpose of proving that what he said respecting a rate of 1d. per ton per mile was wrong, and I gave the authority upon which I based my calculation. I wish *he* were as ready to give us the authority upon which *his* statements are based. Notwithstanding what he says, I *am* astonished, and very much so, that the London and North-Western Company only earns 6s. 3½d. per train mile, and if, as I have shown, the average rate be 1½d. per ton per mile for merchandise alone, independent of the 3,000,000 tons of coal carried, there is left only 50 tons nett per train out of 300 tons gross, exactly one-sixth of the actual weight hauled. The L. and N. W. balance-sheet shows 7,333,371 tons as the nett traffic for the half-year, from which deduct, say, 3,000,000 tons of coal, leaving 4,333,371 tons of merchandise, or double that amount per annum. At one-sixth the actual tonnage hauled, there is the enormous result of 52,000,000 tons hauled per annum, out of which only 8,666,742 tons are productive; the cost of hauling the unproductive weight being precisely the same per ton as the nett tonnage.

In the face of this astounding fact, is it "unjust" or "uncalled for" to characterise such a state of things as squandering the money of the shareholders, to say the least of it; and is it to be supposed that because this is so now, directors are, like "Tender Engine," content that it should continue? I feel convinced that these facts have only to be brought home to the knowledge of the able men who govern our railway companies, and a remedy proved to their satisfaction, to induce them without the slightest hesitation to adopt any system which would give economy as well as efficiency, and lead to a far different return for the capital invested; and I think it is a little too much for "Tender Engine" to assume that those gentlemen are quite content as they are. It is difficult to know how to deal with a logician like your correspondent, inasmuch as he is so chary of his facts and so prolific with his assertions. If he would generalise less, and favour us with more principles, I could get hold of him better.

I am not in the least deceived respecting the three great principles for which I contend, viz.:

1. *Great combined power of traction for either fast or slow trains, the centre line of traction being nearer the centre line of curve than in any other known class of engine.*

2. *Great power of adhesion, distributed in such a manner as to be at least two-thirds less destructive to the permanent way than is the case with any other known class of engine.*

3. *Greater facilities for passing round curves with the minimum of friction and with greater safety than can be claimed by any other known class of engine.*

These are the three great cardinal points I claim, to which may be added the *entire* saving of the cumbersome and costly tenders, and the profit arising from their weight being available for merchandise or passengers, the saving of costly turntables and the space they occupy—a point of no mean importance in our metropolitan railways, and the saving effected by the interchangability of parts, calculated to be the cost of from 7½ to 10 engines out of every 100. Imagine this on the North-Western Railway, where there are about 1400 locomotives.

"Tender Engine" says he has some knowledge of the Vale of Neath Railway. When he has had a better knowledge of it, he will probably change his opinion about 27 tons being all that is required for adhesion; at all events, I trust, because he has said so, he will not use his influence to insist on continuing the 27 ton engine after he has found out that this weight is not sufficient. I beg to assure him that anything I may have said in my replies has not been with any desire to give offence, and if at any time he may have thought so I hope he will forgive me, and attribute all I have said to pure sincerity and a wish to elicit the truth. I am alone in striving to develop a great principle, and the task is not only difficult but beset with many prejudices. I feel and write strongly, believing I am right; and I trust he will thoroughly investigate the principle, and when satisfied, and it is in his power, he will encourage my efforts.

My engine on the Neath and Brecon, to which "Tender Engine" so unfairly alludes, must have the credit for all which has been asserted as to her performances; and her present position is not in the least due to any failure in the principle, but to some minor defects in her construction chargeable to the constructors alone, but which may be pardonable on account of her being the first of her class. When "Tender Engine" is next at Neath, he can learn for himself the truth of what I say.

One word in reply to Mr. Naylor, although I fear I have already trespassed too much on your valuable time and space. I quite agree with him as to the relative powers and loads of the engines he gives; these are indisputable facts. I wish, however, to call his attention to another fact not less indisputable, and that is, my engines are just as applicable and as necessary on "the entire farm of railways on the plains" as they are "amongst the hills." If they are good in the one case, they must be equally so in the other. What Mr. Naylor means, I apprehend, is, that while the present description of tender engines are adapted for railways on the plains, yet they are unable to work amongst the hills, and hence, because my engines *can* work the hills and the others *cannot*, he would send mine to the hills. I regret to have to differ from Mr. Naylor in his reason for supporting the tender, viz., because our "mineral trains are notoriously short of brake power," and "the tender comes into use in place of a third brake van." I fully intended writing a letter against the use of more than one brake van to any train, and that only in the rear, and apply the weights of the extra number now usually used to profitable purposes, for the simple reason that they are not wanted. Mr. Naylor cannot have seen Mr. Clarke's continuous brake in use on the Great Western, North London, and other lines. It is the most perfect in its principle that has come before my notice, and has the advantage of placing the whole train, in one instant, under the command, as it should properly be, of the driver and fireman, instead of that usually employed, as well described by Mr. Naylor: "Although every wagon may have its individual brake, they are not of the slightest use in preventing an unexpected collision, from the fact that they cannot be got at in time to be of any service."

Mr. Clarke's brake can be applied by the driver or fireman to every individual wagon supplied with the apparatus without his moving from the engine, and I am surprised that our very able Government inspectors do not insist on all trains being supplied with this or some other equally good continuous brake, under the control of the enginemen. Brakes should also be applied to all locomotives, but in a form different to that of the ordinary brake. I have often thought that a force similar to that applied for starting a train should be the medium employed to stop it—I mean the cylinders—through the couplings to the wheels. Mr. de Bergue, of Manchester, some time ago gave me particulars of a system which he patented for effecting this object, and I believe a most effective system it is. It consists of an air chamber weighted to the necessary pressure per square inch, into which when it is wished to stop a train the air is pumped, which, when an engine is reversed, usually goes into the boiler. A simple arrangement, sufficing to cut off the passage of the air to the boiler, turning it into the chamber, where, with one or two revolutions of the engine, the pressure is greater by any amount required beyond that in the boiler, and of course this pressure is communicated to the piston on the reverse side to that on which the engine is travelling. I am confident this is the proper brake for engines, and much more effective than any skidding, and in this way the engine itself will stop a train without any other assistance in the same or less time that it took to start it and get into velocity, in proportion to the retarding and starting pressure.

Apologising for the great length of these remarks,

I beg to remain yours obediently,

Robt. F. Fairlie.

56, Gracechurch-street, London,
Dec. 24, 1866.

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*To the Editor of Engineering.*

Sir,—As one of your habitual readers I have followed with interest the recent correspondence on the subject of special locomotives, which appears to me to turn principally upon a comparison between Mr. Fairlie's system, so called, and that in general use—viz. engines with tenders.

It would be unfair, I think, to Mr. Fairlie to refrain from acknowledging many good points of principle in his designs; but there are many practical difficulties to be considered, and he appears to me to err in claiming to be the sole inventor or advocate of making the whole weight of engines available for traction.

Most of us are familiar with lines on which tender engines are unknown, and tank engines only have been for many years in use. Of these several are six-wheeled coupled tank engines weighing 40 tons, all tractive.

The South Devon and Cornwall Railways, amongst others, may be referred to as main trunk lines, having been worked on this system since their opening, and are singled out by reason of their exceptionally heavy gradients and sharp curves; the gradients over a not inconsiderable portion of the system being 1 in 45, and their curves being of such radius as would, if anywhere, call into requisition the Fairlie engine. Mr. Fairlie seems to assume that no other system but his own admits of the employment of large engines for the sharp curves necessitated by modern engineering. I cannot hold this view; for in all cases in which one powerful monster may be insufficient, two tank engines properly coupled together, by means well known, offer the identical advantages claimed by his system, whilst they certainly contain the inestimable advantage of being free from the complexity of Mr. Fairlie's double engine, and are capable of being disconnected in a few minutes, the one from the other, and so become immediately available for regular traffic.

The accompanying sketch shows the Fairlie double engine, and a pair of twin engines on a sharp curve.

It has been stated that twin engines have been tried and discarded as a system, but my experience is quite opposed to such assertion. The foregoing proves their satisfactory employment. It is quite true that the combined effort of one engine having, for example, eight coupled wheels, driven as one engine, is more effective than the same weight and power distributed over two distinct engines. Hence the occasional and logical employment for exceptional traffic of eight-wheel coupled engines.

If it be said that twin engines require two enginemen and firemen, I freely admit, and contend that in practice it will be found that Mr Fairlie's double engine cannot be safely worked by one engineman and fireman. Even if it were possible for two men to take charge of a 72 ton double engine, the saving would be very slight, for assuming the average cost of locomotive working for goods engines to be 13d. per mile, the enginemen's wages do not exceed 1½d. per mile.

It may be mentioned, that on the lines referred to—viz. the South

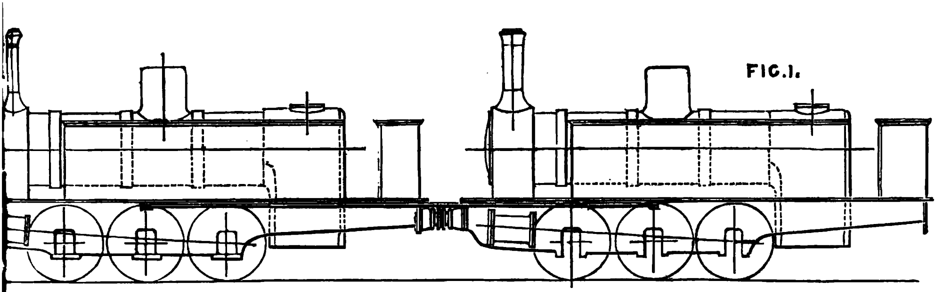
FIG.1.

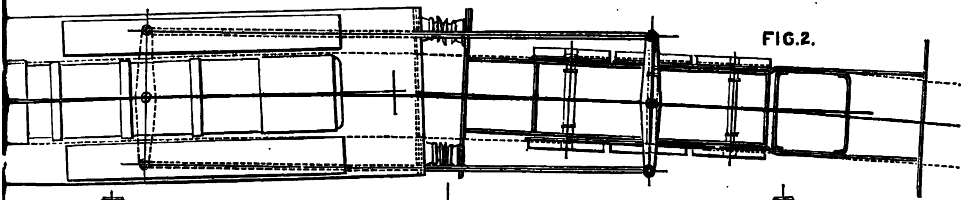
FIG.2.

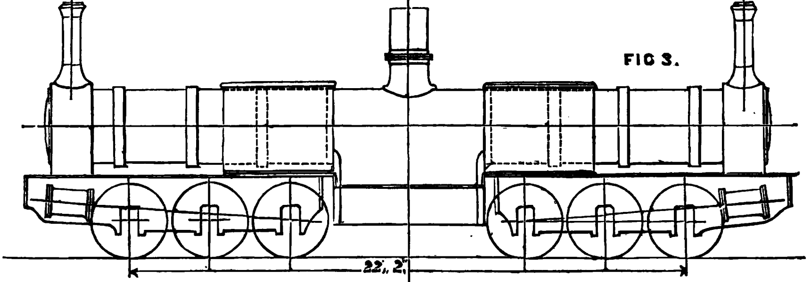
FIG 3.

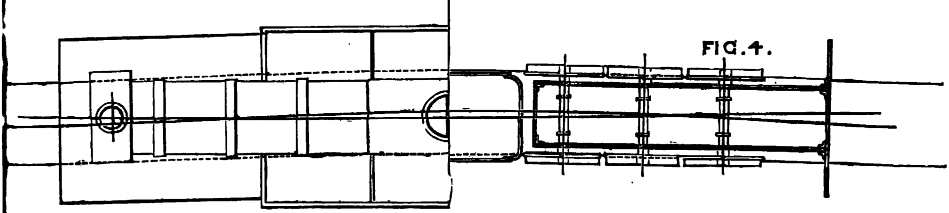
FIG.4.

Devon and Cornwall, all the goods trains working over the more difficult sections, are drawn by two ordinary six-wheel coupled tank engines, coupled together by the usual draw-bar. They work without the slightest inconvenience round the sharpest curves on trunk lines in England, and have so worked during many years. The gross weight of the two engines, including seven tons of water and fuel to each engine, represents 80 tons, all tractive, a traction sufficient, I imagine, to satisfy Mr. Fairlie.

It is true that the position of the two engines thus coupled is not so favourable, theoretically, as that of the double Fairlie engine but other modes of coupling, which might have been resorted to, have not been called into requisition because it has been thought unnecessary, and it has been preferred to maintain the simplicity of the old-fashioned draw-bar. It is possible that it might be desirable for the South Devon engines to be coupled at a point over their central axles (see sketch), because continental experience on this point shows that no practical inconvenience attaches to the system.

Time alone will decide whether it is desirable to encounter the complex jointing of steam and exhaust pipes through the supporting centres, radial couplings, &c., of Mr. Fairlie's system; but I can conceive no case where the object sought for by Mr. Fairlie may not be attained by the types of engines in constant present use on railways in this country.

I do not think it desirable in all cases to make use of the entire weight of engine for traction. For main lines tenders will continue to be employed, and no passenger trains will ever require more than four coupled wheels; but I would cite among many modern systems in which tenders are discarded, the four-wheel coupled tank engines in use on the Great Northern and South Eastern Railways for their metropolitan and city traffic; the former carrying 1000 gallons of water and 30 cwt. of fuel, say together 6½ tons of varying weight, non-tractive, upon a single Adams's radial axle in a tank, coalbox, and apparatus weighing about 55 cwt., including the wheels and axle; the latter (South Eastern) carrying 1200 gallons of water, and 30 to 40 cwt. of fuel, say 7 tons of varying weight, non-tractive, on a traversing bogie with four wheels, in a tank and coalbox weighing about 4½ tons including bogie and wheels. These non-tractive and varying weights are carried on wheels and axles so disposed as not to affect appreciably or at all the fixed weight upon the engine proper, which is entirely tractive, and of course proportional to the required duty.

The North London locomotives are also tank engines, no tenders being employed.

I do not think that any practical engineer would venture to prefer Mr. Fairlie's system of double engine to the entire simplicity of the types cited, or to assert that it possesses advantages in passing round curves which these do not possess, and I much mistrust the judgment which made selection of the double engine for the Queensland Railway, when two simple engines, having either four or six wheels coupled, representing precisely the same power, might have been employed twin fashion when required, and separately when required, coupled over their central axles, and so giving the identical disposition claimed by Mr. Fairlie as belonging to his system, but, as before suggested, attainable in the system of twin engines scientifically coupled. Practical men may also fairly doubt the expediency of allowing the whole weight of the boiler to rest upon pins through which the steam is to be conveyed to the cylinders. Such practice, it may be assumed, should be resorted to only in case no other method should be open to locomotive engineers.

I desire to guard your readers from supposing that in these few remarks my aim has been to intimate that Mr. Fairlie has not done good service to the cause of locomotive working, still less that he has been actuated by any other motive than that of submitting a type of engine which he really believes to offer unique advantages. If I have any special object in addressing you, it is to elicit from other practical engineers their honest judgment upon a matter carrying with it an importance not to be exaggerated.

While on the subject of locomotives, tractive power, &c., I notice a communication in your paper of 21st ult. from one of our most able practical engineers, I mean Mr. William Naylor, in which he compares the tractive powers of certain engines upon an invariable formula—viz. by multiplying the area of cylinder by the pressure and collective stroke of pistons, and dividing by the periphery of driving wheels, without taking into consideration the number of driving axles, which vary from one, in the case of independent engines, to four in the case of the exceptional eight-wheels coupled engines. Surely the element of number should enter into the formula? Perhaps Mr. Naylor may explain.

I am, Sir, your obedient Servant,

TANK ENGINE.

January 5th, 1867.

[If "Tank Engine" reconsiders the matter, he will see that the number of driving wheels in no way affects the amount of tractive force which the cylinders are capable of exerting, although it of course depends upon the amount of adhesion possessed by the engine whether this force can be made available or not.—ED. E.]

*To the Editor of Engineering.*

Sir,—Your correspondent "Tank Engine" cannot have seen the whole of the correspondence that has lately taken place on this subject, notwithstanding all he avers to the contrary, or he never would have penned the letter which appeared in your columns last week, nor would he have produced the diagrams which accompanied it, had he given the subject that consideration it really merits. I am as anxious as "Tank Engine," or other of your correspondents can possibly be, to have this most important question thoroughly discussed, having perfect confidence in the result being the adoption of the principle I advocate; but I must again request that your valuable space and my time may not be taken up with all kinds of unnecessary matter, whether right or wrong, that may be foreign to the subject; and that when any point or points have been discussed, and arguments employed for or against, they should follow up such argument on either side, recognising what has been already said, instead of stating as a fresh argument that which has already appeared and been disposed of. I wish it, therefore, to be understood that I shall only take notice of and reply to any correspondent who sets forth some new objection, or who attempts to prove that any of the great principles I claim for my system are based upon false premises.

There are two distinct instances of what I justly complain in "Tank Engine's" letter, which he begins by disparaging me, as if to do so would help his arguments; and, although the latter are couched in very nice phrase, yet the object is apparently to throw discredit upon me. I allude to the words "on Fairlie's system *so called*," as if I had no right to the title. "And he appears to me to err in claiming to be the sole inventor or advocate in making the whole weight of engines available for traction." Now, I call this all foreign to the main question, as, on the one hand, it can matter very little to the principle what name it shall be called; and, with regard to the other assertion, it is simply as absurd as it is untrue. I have never by word or deed made any such claim; on the contrary, I have recognised tank engines as a move in the right direction. This is clearly proved in the pamphlet which I wrote on "Locomotive Engines" when my patent was published; and if "Tank Engine" will send me his address, I shall have much pleasure in forwarding him a copy, and if he will take the trouble to look over it carefully, he will find not only his accusation unfounded, but the whole of the assertions set forth in his letter clearly and unanswerably explained.

I know nothing whatever about the South Devon or Cornwall Railways, and of course readily admit they are worked by 40-ton tank engines; but this I can assure your correspondents, that the shareholders of these lines will not get rich on the dividends they receive. And if the engines are at all like the sketch given by "Tank Engine," I don't wonder at the cost of the locomotive power being 13d. per mile. See how this compares with the London and North-Western Railway, which, according to the statement in the letter of your able correspondent, "Tender Engine," which appeared in your journal a few weeks ago (pages 415 and 416, November 30th, 1866), is worked at a cost of only 8d. per mile, or less than two-thirds the cost of the lines referred to by "Tank Engine;" and further, 13d. being the cost of the locomotive power per mile, what must the cost of the maintenance of way be, which bears a relative proportion to the other? It must be something enormous, and the sooner the managers of these lines wake up to this state of things and dismiss for ever the 40-ton tank engines, the better for their reputation as managers, and certainly the better for the shareholders' pockets, although, taking "Tank Engine's" own view of the case, these gentlemen are the last that should receive a moment's consideration. For does he not say, with a great flourish of trumpets, "Most of us are familiar with lines on which tender engines are unknown, and tank engines only have been for years in use. Of these several are six-wheeled coupled tank engines weighing 40 tons, all tractive." Again, he says, "The South Devon and Cornwall Railways, amongst others, may be referred to as main trunk lines having been worked on this system since their opening;" and he further adds, "It has been stated that twin engines have been tried and discarded as a system, but my experience is quite opposed to such assertion. The foregoing proves their satisfactory employment."

Let us see what this satisfactory employment is. I find, during the month of December, the 100*l*. stock of the South Devon Railway ranged from 47*l*., the highest, to 43*l*., the lowest—considerably below 50 per cent. discount, and the Cornwall Railway 20*l*. shares, for the same month, ranged between 4*l*. and 6*l*., or 75 per. cent. discount. If this is the result of a *satisfactory employment* of the tank engines, then of course I have nothing more to say, but mourn over such wasteful squandering of the shareholders' money.

I find from the sketch of the twin engines given by your correspondent, that each measures 25 ft. from end plate to end plate, and weighs 40 tons on a wheel base only 8 ft. between extreme centres, while the heaviest part of each engine, viz. the firebox and coal-bunker, extends 10 ft. behind the centre of the trailing axle. Your readers will see at a glance that such an engine could not work on any line, therefore I need not attempt to prove it. In this case, "Tank Engine" has misrepresented his favourite.

One penny farthing per mile on the cost of the locomotive department seemingly being nothing in the opinion of "Tank Engine," leads me to believe he has something to do with the South Devon and Cornwall Railways, where it would appear they can afford to spend 13d. per mile for this department alone. Notwithstanding this, however, 1¼d. per mile amounts to about one-eleventh of the cost of locomotive working on the lines just mentioned, while it would be a little over one-sixth on the London and North-Western.

It is simply ridiculous to allege "if it be said twin engines require two enginemen and firemen," and then "freely admit it," and to follow this up by "contending that in practice it will be found that Mr. Fairlie's double engine cannot be safely worked by one engineman and fireman." Pray look at his sketch of the twin engines. Surely if "Tank Engine's" experience of the lines he mentions is so great as he would lead us to suppose, he could inform us whether the twin engines are worked by one engineman and fireman, without putting it as he has done. "If it be said," &c.

My reply to that portion which bears on my engine is that one of these engines has been working for the last twelve months on the Neath and Brecon Railway, with one engineman and fireman, and it would be just as reasonable to put two men to drive one horse, each having hold of the reins, as to put two enginemen and firemen on any of my engines, which have but one reversing lever, one regulator, one water gauge, &c., precisely as in an ordinary single engine.

The remaining portion of "Tank Engine's" letter is full of assertions, such as that "the twin engines are infinitely superior to my engine for all purposes," a simple repetition of "Beta's" assertion, and, in like manner, not giving one single practical illustration or reason.

"Tank Engine" should carefully read over my reply to "Beta," that appeared in your journal, page 486, 21st last December, which he will find practically sets aside all his assertions.

Before concluding this letter I would ask any practical locomotive engineer to imagine the effect that would be produced on the engines and permanent way by working two such engines as shown in "Tank Engine's" letter, having an 8 ft. wheel base, with a firebox and bunker extending behind the trailing axle 10 ft., jerking and pitching at a speed of twenty miles an hour; all that I can say is, I should not like to be the engineman or fireman.

"Tank Engine" will greatly oblige if he will inform me how the forty tons is distributed over the three axles, and the distance allowed for clearance between the top of the trailing axleboxes and frame, on the receipt of which I shall perhaps be able to give him a little information that will clear his perception respecting the advantages of my principle over the twin engine.

I remain, Sir,
Your obedient Servant,
ROBERT F. FAIRLIE.

56, Gracechurch-street, London,
January 15, 1867.

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*To the Editor of Engineering.*

SIR,—Having read with considerable interest the recent correspondence on locomotives, I beg you will allow me a small space to offer a few remarks on the subject. In last week's number, your correspondent, "Tank Engine," says, that two tank engines properly coupled together, by means well known, offer the identical advantages claimed by Mr. Fairlie's system. I think he has not made himself thoroughly acquainted with that system, or he would have formed a very different opinion. In my experience I have never, nor do I think he has, seen a tank engine with the weight equally distributed over all the wheels: this might be done with a certain quantity of water and fuel on starting a journey; but as these get used up, that equilibrium so much required disappears, and with it the steadiness of the engine, while, by Mr. Fairlie's system, this variation cannot possibly occur, as the whole weights of boiler, tanks, water, and fuel, rest upon three points on each bogie, and are arranged in such a manner that any increase or decrease of weight cannot affect one wheel more than another. This, with the swivelling of the bogies, does not only contribute to the steadiness of the engine, but effects a very considerable saving in wear and tear of the permanent way, and increases safety by reducing the liability to running off the line.

As to Mr. Fairlie's engine being adapted for special work only, this is a mistaken notion. I have had the opportunity of riding on the foot-plate of one of his engines, while running over very bad roads, points and crossings, and sharp curves, and certainly there was no perceptible difference between that and running on a straight line; nor could I see that the driver and fireman's duties were in any way increased.

"Tank Engine" seems to think there is an advantage in connecting two small engines together for special work, which are capable of being disconnected in a few minutes, and so made available for regular traffic; if so, why use heavy engines at all? If convenience is any consideration, I should prefer an engine which is adapted for any emergency, one which will only call into requisition two men instead of four, that will take either a heavy or light load, and run quick or slow, as required.

Of the economy to be effected on the permanent way by using Mr. Fairlie's engine there can be no doubt; take, for instance, his engine with two bogies on eight 6 ft. wheels, four cylinders 12 in. by 20 in., and a four-wheel coupled tank engine of the ordinary type, with 6 ft. wheels, and two cylinders 17 in. by 20 in. Let the four-cylinder engine weigh 32 tons, and the other have the same weight on her driving wheels, the traction power with the same pressure would be equal; the former would have four tons on each wheel, while the latter would have eight, but would require to weigh eight tons more to put sufficient weight on the leading or carrying wheels. Either of these engines would be well adapted for passenger traffic, but Mr. Fairlie's engine would certainly be the most economical and safe.

It may be said that there are more parts in the working gear to get out of order; if so, they are much lighter, and offer less resistance to the steady working of the engine, and consequently increased safety at high speeds.

There are many more important points to be discussed in Mr. Fairlie's engine which, I trust, will be taken up by those who are much better able to explain them than

Your obedient Servant,
Bogie Engine.

January 12, 1867.

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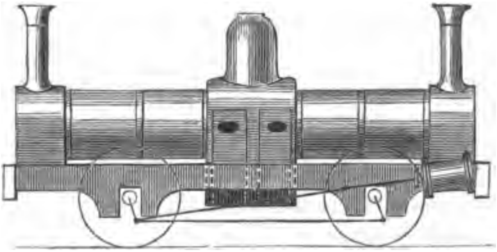
*To the Editor of Engineering.*

Sir,—It may be interesting to those of your readers who have followed the able and temperate discussions in your pages on Mr. Fairlie's locomotive, to know that there were in the year 1862 (and probably are still) two tank engines working on the line of railway between Naples and Cava, with boilers constructed with a central firebox, two barrels and two sets of tubes, and a chimney at each end. If I remember right, there are two internal fireboxes, and the general arrangement is something like this sketch. The engines are very light, and there are only two pairs of wheels, which are coupled; the cylinders—one pair only—are outside, as is also the valve gear. They were designed and built by Mr. Pattinson, the locomotive engineer of the line, whose object probably was simply to obtain a well-balanced tank engine on four wheels without excessive overhang. Water-tanks are placed on each side of the boiler barrels, and coke is carried in sacks on the footplate.



The circumstance of such engines as these having been constructed does not detract in the least from any merit due to Mr. Fairlie for his ingenious arrangements, but it seems only fair to Mr. Pattinson that the fact should be known.

As much has been said on the subject of coupling two tank engines together, I may observe that there is a patent in existence for coupling them together back to back, so as to be under the control of one set of handles, the boilers being also connected.

I am, &c.,
L. E. W.

January 14, 1867.

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*To the Editor of Engineering.*

Sir,—As the writer of the letter signed "Tank Engine" in your number of the 11th inst., on which Mr. Fairlie comments in his letter in your edition of last Friday, I request permission to offer a short explanation, avoiding all irrelevant matter.

The diagram annexed to my letter represented Mr. Fairlie's engine of the Queensland Railway, copied from the engraving given in your number of November 30th.

The twin engine placed in juxtaposition with it is of identical proportion as to the separate wheel bases of either engine, but, by reason of the required foot-plate arrangement, the total wheel base is extended from 22 ft. 2 in. extreme centres of Fairlie's to 26 ft. 6 in. extreme centres of twin engine. I cannot with the nicest measurement understand where Mr. Fairlie finds 25 ft. from end plate to end plate. I make it 19 ft.

The twin engines have nothing in common with the South Devon goods tank engines. The wheel base of these engines is 15 ft. 6 in., instead of 8 ft. The overhang of their footplate is 5 ft. 6 in., instead of 10 ft., the difference in each case amounting to about 100 per cent. So that any argument based upon such incorrect data naturally collapses.

Mr. Fairlie prudently says, "If the South Devon engines are at all like the sketch, I don't wonder at the cost of the locomotive power being 13d. per mile."

It is childish to attempt any comparison between two lines so utterly distinct as the South Devon and London and North-Western lines. The capital account of the first mentioned has been unduly enhanced by the experiment of the atmospheric system, representing some 350,000*l.* literally thrown away, a large proportion of a small capital. Then the gradients and curves are of the most difficult character; the cost of fuel double that of the London and North-Western. The one is an agricultural district, the other passes through the most densely populated district of England, and terminates at the metropolis.

I have no authority for putting the cost of locomotive working at 13d. per mile, and used the word "*assuming*;" but even if it were so, it would not compare unfavourably with the London and North-Western at the average cost of passenger and goods trains, the latter of course exceeding 8d. per mile.

I have only now to answer Mr. Fairlie's last question how the 40 tons of the South Devon engines are distributed over the three axles. My reply is that each axle with a full saddle tank placed on the three axles, which cover a wheel base of 15½ ft., carries as nearly as possible an equal weight of 13 tons 7 cwt. The distance allowed for clearance between the top of the axleboxes is 1¾ in. I have never known steadier engines.

To conclude, I have no object but to elicit the temperately expressed opinion of practical engineers on the subject, and repeat that I am fully alive to, and readily admit, many good points in Mr. Fairlie's system. I do not admit, however, that there is anything in it as compared with other known systems which is capable of affecting the dividends of railway proprietors.

I had quite intended that my first letter should have been my last, and would have adhered to this intention, but for the inaccuracies of figures so gross as those into which Mr. Fairlie allowed himself to fall.

I now withdraw from further correspondence.

I remain, Sir,
Your obedient Servant,
TANK ENGINE.

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*To the Editor of Engineering.*

SIR,—Your correspondent, "Tank Engine," has again favoured us with his views on this subject, which to me appear as mystical as some of those expressed in his former letter, and to which I should not have considered it necessary to reply were it not that in the concluding paragraph he observes, "but for the inaccuracies of figures so gross as those into which Mr. Fairlie allowed himself to fall."

I do not like to err in figures if I can help it, therefore referred back to the diagrams which accompanied "Tank Engine's" letter in your number January 11th, and find, as any one else can who will take the trouble to look, that if, as he admits, the wheel base of his twin engines is 8 ft., the distance from end of footplate to leading end-plate must be very little short of 25 ft. I scaled the diagrams at $\frac{1}{10}$th of an inch to the foot, assuming the wheels to be 4 ft. diameter. "Tank Engine" tells us in one breath the twin engine is better for all purposes than my engine, while in the next I can fancy seeing him heave a deep sigh, and say, Thank Heaven, the South Devon engines are *not* like the diagram of the twin engine; were this so, Mr. Fairlie might well call attention to the cost of haulage being 13d. per mile. He says, "This style," meaning the twin engine, which he shows on a curve with a view to prove they are, even in this respect, equal to my arrangement, "of engine has nothing in common with the South Devon goods tank engines, the wheel base of which is 15 ft. 6 in." He admits the twin engine as shown is an impossibility, while he illustrates it as a proof it is equal to mine: this is a method of reasoning that "no fellah could understand." Given a 20 chain curve to a 15 ft. 6 in. wheel base, what curve will an 8 ft. wheel base give?

I have seen and heard many queer things, but I never, before the appearance of "Tank Engine's" last, understood that the capital of a company had anything to do with the cost of locomotive haulage per mile. If this were so, the North London, Metropolitan, and Blackwall Railways ought to cost at least 2s. 6d. per mile. The gradients and the curves—"ay, there's the rub"—worked with 40-ton tank engines on six wheels with a wheel base of 15 ft. 6 in. This is where the money goes. To keep up such stock, and to keep up the road (which includes the rails, chairs, sleepers, and substructure generally all suffer alike) on which they have to travel, would, in my opinion, reduce any company to the state of the South Devon and Cornwall Railways. It is these enormous never-ending expenses that "take all the gilt off the gingerbread," leaving the poor shareholders to go supperless to bed.

I ask "Tank Engine" in all seriousness how he can pretend to say that any engine on six or eight wheels can be so useful and yet so easy on the permanent way, and consequently on the engine itself, as my engine?

It is only required to imagine the result to the permanent way of a rolling mass of 40 tons borne on six points, swaying by the inevitable never-altering inaccuracies of the road, backward, forward, and from side to side, increasing the normal load on each wheel from nearly 7 tons to sometimes as much as 12 tons, every roll from wheel to wheel representing a blow as from the heaviest steam-hammer on the rails, to be immediately convinced that any single or twin engine cannot for one instant compare with my arrangement.

Supposing the weight on the wheels of one of my engines to be the same as that on the wheels of the 40-ton engine when at rest, the destruction to the engines and the permanent way would be in exact proportion to that weight (say 7 tons) and the 10 or 12 tons that would be on the wheels of the 40-ton engine, by oscillation more than 50 per cent. in favour of my engine over the single one. The value of this 50 per cent. is enhanced by the fact that every ton brought on a rail beyond its power of sustainance, before crushing, multiplies the injury thereto by more than three times; the foregoing together with the facilities for passing curves, keeping the centre of traction in the centre of the line, and reducing the friction to a minimum under all circumstances, are some of the advantages I claim for my system, which are "capable of affecting the dividends of railway proprietors."

I remain, Sir, your obedient servant,
ROBERT F. FAIRLIE.

56, Gracechurch-street, London,
January 29, 1866.

[We trust that all our correspondents have now disposed of this subject, each to his own satisfaction. Our own conclusions will be found upon another page.—ED. E.]

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In closing the correspondence which has been reprinted in the foregoing pages, the editor of *Engineering* summed up the matter as follows:

## LOCOMOTIVE ENGINES.

*Extracted from Engineering, February*: 1, 1867.

THE protracted discussion which has taken place in our columns upon Mr. Fairlie's engine is one of the most important which has appeared for several years upon the subject of locomotives. Although writing, in many cases, over *noms de plume*, several parties to the discussion are locomotive engineers of the highest eminence—locomotive builders and locomotive superintendents of some of the leading English lines, and whose names, were we permitted to publish them, would alone carry great weight.

That this discussion has served to direct the attention of railway managers, and in many cases of railway shareholders, to one of the most important questions of railway economy, viz., the proper adaptation of locomotive power, there can be no doubt. In closing it, we do not purpose to review the remarks of each writer, but merely to add a few words upon the general question involved. We have only to look back a very few years to see that the requirements of locomotive power and the weight of locomotives have greatly increased, and we know that they are yet increasing. We have now actually at work upon two English lines a small number of tank engines of 56 tons weight each, and there are goods engines on at least two of the French lines weighing 44 tons without their tenders, and upon one of these lines there are tank engines of 59 tons weight. All these engines have parallel axles, four pairs of wheels being coupled in the 56 and 44-ton engines, while in the heavier tank engines six axles are arranged in two groups of three each, each group being coupled and driven by a separate pair of cylinders. It is chiefly with reference to engines of great weight that we desire to consider Mr. Fairlie's system, although we have no wish to deny its applicability to lighter engines. It is in the case of heavy engines that its advantages of an equal distribution of the weight upon eight, ten, or twelve wheels are most apparent, and it is well known that much heavier goods and coal trains than are now taken could be worked with economy, were there a practicable engine of sufficient power, without an excessive weight upon a single pair of wheels. We shall not repeat here our former arguments against twin engines, or, in other words, the system of two separate engines coupled together; but we cannot admit that they are to be considered in dealing with the question of very heavy trains or steep gradients. Mr. Fairlie's plan admits of 60-ton engines with but 5 tons on each wheel; and as the separate wheel base of each bogie need not, with 4½ ft. wheels exceed 9 ft. 6 in., they will traverse curves of from 6 to 10 chains radius with ease. No one has denied nor perhaps greatly underrated these advantages, but objections have been raised to the details of the plan. We have never approved of the quadrant links by which Mr. Fairlie connects his bogies together, but these he has arranged to dispense with, employing in their stead a continuous framing along the sides of the engine, the whole pull between the bogies being through this framing. A clever locomotive-designer would have no difficulty in making a good job of this framing, so that it should be at once light, strong, and stiff, while forming a perfect connexion between the bogies. Another and an important question is, Can the pull of each separate group of coupled wheels be properly transmitted to the upper frame of the engine, and through this to the train, through a bogie pin? The tendency must always be, so long as either bogie is pushing the engine forward, to throw weight off the front upon the hind wheels of each bogie, and the proportion in which the weight is distributed upon the separate wheels when at rest will be changed when the engine is working with a heavy load. With 16 in. cylinders, 2 ft. stroke, 4½ ft. wheels, and 100 lb. steam, each bogie would have a steam tractive force of about 5 tons, and this force would act to tip the bogie down behind in proportion to the height of the bogie pin above the axles, and to the shortness of the wheel base. But as respects the question of pulling sideways through a bogie pin, we believe that a pin or flat-bottomed circular disc, as it should be, 10 in. or 12 in. in diameter, and resting upon a flat seat, would be found to work well and give no trouble. We believe Mr. Fairlie's engines, already at work, have shown no weakness in this respect; but, of course, they have been but a comparatively short time in use.

As for carrying the steam and exhaust pipes through the bogie pins, we think this point may be well worked out by most clever designers. There is no vertical movement to provide for, and the occasional and comparatively slight angular motion around the pin could be as easily compensated as that of an oscillating engine trunnion, making hundreds of thousands of vibrations successively in the case of an ocean steam-ship.

Another point is the arrangement of the reversing gear, so that the valve gear of both bogies shall maintain its given position when the engine is going round curves. Mr. Fairlie has worked out an arrangement of quadrant guides for this purpose, which, although a little complicated in appearance, really works easily and accurately,

As for the engine-driver and fireman being separated, we see no great objection in this, for they are yet within each other's sight and hearing, and, with a modified form of fire-box, they may easily step over from side to side. The firing is no more difficult sideways than endways, and there is nothing in the double-ended boiler—certainly nothing if it be made with separate fire-boxes—to place it at any disadvantage in its steaming powers, while the water level is better maintained on steep inclines than is the case with ordinary boilers.

Objections may be raised with some justice as to the dust from the footplates falling into the working parts below, or rather behind. This, however, can be in a great measure prevented by making the footplates quite tight and close, with a trap in the middle in which to sweep the dust.

As for the greater complication of four cylinders and sets of valve gear, we are not disposed to give great importance to this objection. It is of far less consequence, in our opinion, than the increased stiffness and concentrated weight of a six or eight coupled engine of the same power. For our own part, we would not employ four cylinders if they were unnecessary, but in the case of very powerful engines we believe it would be better to at once reconcile ourselves to four cylinders than to load a single pair of wheels with from 12 to 15 tons. It is for engines of great power that Mr. Fairlie's system is best adapted, and we differ from some of our correspondents in believing as we do that—as has been found upon the French lines—we need only an improved plan of engine to enable us to work up to a considerably greater power with economy. We have gone as far in increasing the size of our present engines as their plan will admit of, and it is, we think, in the restrictions imposed by their plan, rather than in any absolute objections to engines of from 50 to 70 tons weight, that we have not already adopted engines of increased power.

THE END.

LONDON:
PRINTED BY C. WHITING, BEAUFORT HOUSE, STRAND.